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THE ORIGIN OF THE GOLD DEPOSITS OF MATACHEWAN DISTRICT, NORTHERN ONTARIO.[1]

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INTRODUCTION.

The gold of Matachewan district was originally part of a granite or quartz syenite-porphyry magma. As the magma crystallized the gold became concentrated in the still liquid volatile residue, and was finally deposited from it along with pyrite. Consequently the gold is found in satellitic intrusive bodies which range from dikes of granite porphyry through pegmatites of varying degrees of silication to veins of pure quartz. It is also found in the country rock adjacent to the dikes and veins, which has been calcitized and pyritized for considerable distances from their walls.

The present paper is intended only as a preliminary statement of the more outstanding facts observable in the present undeveloped state of the discoveries. It is hoped that as mining operations advance, evidence will be obtainable which will render possible a more accurate and extended description than can be here attempted.

Matachewan district derives its name from an old Hudson Bay trading post on the Montreal river of Northern Ontario. The gold discoveries are in Powell township, about 5 miles southwest

[1] Published by permission of the Director of the Geological Survey of Canada.

of the post, between the east and west branches of the Montreal river. They are most easily reached from Elk Lake, the terminus of a branch of the Timiskaming and Northern Ontario railway. From Elk Lake the traveller may proceed the remaining 30 miles up the Montreal river to the mines, by canoe or launch. Fig. 15 shows the relative location of Powell township.

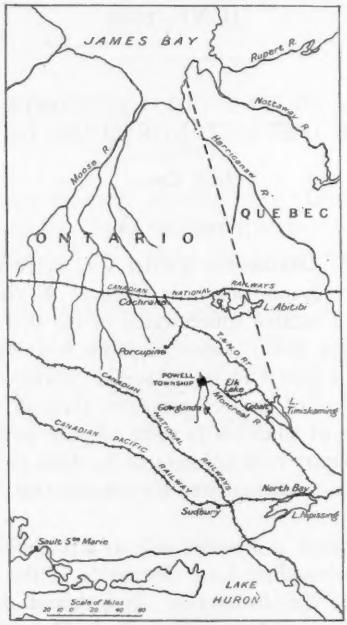


FIG. 15. Sketch map of northern Ontario, showing location of Powell Township.

The first discoveries were made by J. Davidson and S. Otisse in 1916. The report of their finds was followed by a rush of prospectors into the area, and the district for several miles around was staked. Little has been found as yet outside of the original Davidson and Otisse claims, although this may be due in part to

the fact that the depletion of the labor supply by the war has rendered intensive prospecting impossible, except in a few instances. Prospecting is especially difficult, as the drift cover is heavy except in the neighborhood of water courses.

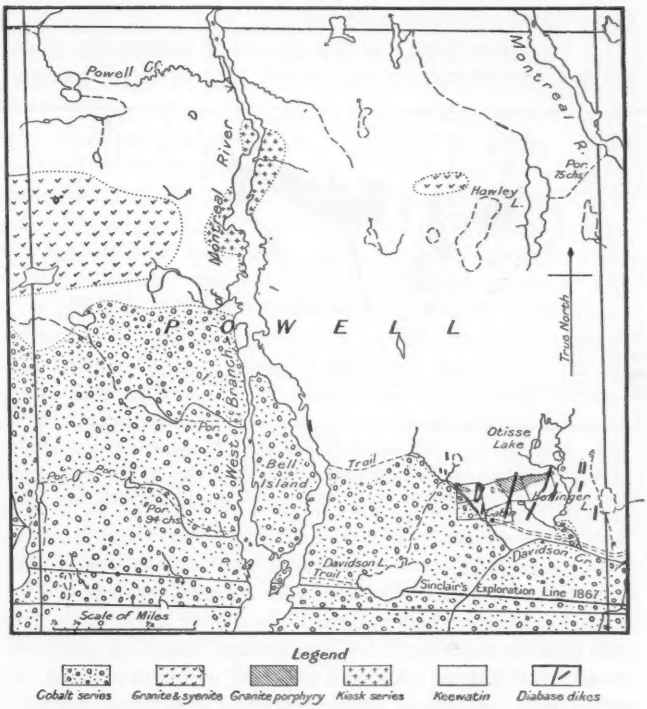


FIG. 16. Powell Township, northern Ontario. The claims outlined near Davidson Creek are those on which the main gold discoveries have been made.

Considerable development work was done on the Davidson claims during the summer of 1917 (see Fig. 17). Exposures are naturally good on these claims, situated as they are in the valley

of Davidson creek; and were materially improved early in 1917 by a forest fire, which swept the southern part of the township and removed entirely the surface covering of timber, shrubs, and moss. Development work consisted of trenching particularly over the surface of the porphyry intrusives, and the erection of three substantial buildings.

On the Otisse claims a certain amount of exploratory trenching and development was done during 1917 by Mr. Otisse, and

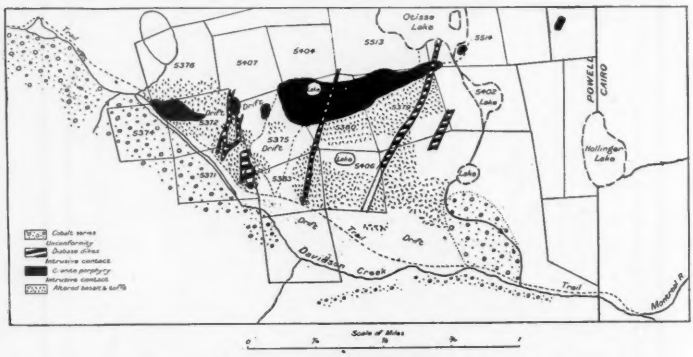


FIG. 17. Geology of the gold district. Davidson claims, Nos. 5371, 5372, 5374, 5375, 5383. Claims of the Colorado Ontario Development Co., 5379, 5380, 5402.

about the end of the year claims 5379, 5380, and 5402 were sold to the Colorado Ontario Development Company, which proceeded in 1918 to develop them systematically. Over claims 5379 and 5380 trenches were dug 100 feet apart, and where indications of ore were encountered additional trenching was done between the earlier ones. In August, when the surface exploration was well advanced, diamond drilling was begun to determine the underground extension of the ore bodies.

On account of the comparative lack of development on other properties, the attention of the writer was confined to these two, and somewhat more especially to the latter, since it presents features of greater complexity and interest.

GENERAL GEOLOGY.

The geology of the district is similar to that of Timiskaming district in general. At the base of the geologic column lies the series of rhyolites, andesites, and basalts, with tuffs of corresponding compositions, which have commonly been referred to in the literature as "Keewatin." The rocks are in most cases greatly altered, and the original constituents more or less completely converted into secondary minerals such as chloride, hornblende, kaolin, sericite and epidote, in places also the rocks have been converted into schists. Here and there throughout northern Ontario the lavas are overlain unconformably by sediments known locally as Timiskaming series, Sudbury series, Kiask series, etc., but as these are not found near the gold deposits they will not be further mentioned. After the deposition of the sediments an intense regional folding compressed sediments and lavas into close folds, and converted great portions of them into schists. Following the folding came the intrusion of great batholiths of granite and syenite. The syenite porphyry of Matachewan district is one of these intrusions, its magmatic relationships to large bodies of quartz syenite lying to the south and west are shown by close similarities in chemical and mineralogical composition.[2] Both the syenite and the porphyry are cut by large dikes of a rather fresh-looking gabbro characterized in places by a great development of large plagioclases, which have attained diameters of several inches.

After the granitic and other intrusions, a long period of erosion occurred, and the region was reduced to a peneplain of about the same contour as at present, on the surface of which the Cobalt series was laid down. This series which is largely of sub-aërial origin, is the probable equivalent of the Middle Huronian of the south shore of Lake Superior. Later, probably in Keweenawan time, great intrusions of the Nipissing diabase took place, forming sills in the Huronian and dikes in the underlying rocks. These intrusions were the source of the silver ores of Cobalt and Gowganda, and the copper-nickel ores of the Sudbury dis-

[2] Burrows, A. G., Ont. Bur. of Mines, Bull. 34, pp. 15–17.

trict. Gentle folding movements followed the intrusion of the Nipissing diabase, throwing the beds into open folds with dips rarely exceeding 25 degrees. The shearing and metamorphism characteristic of the older rocks is rarely found in the Cobalt series and the later diabase, which are commonly as fresh as if formed during the Tertiary.

The regional geology may be summed up in the following table:

Nipissing diabase.....Keweenawan.
Intrusive contact.
Cobalt series.....Middle Huronian. (?)
Great unconformity.
Diabase dikes.
Intrusive contact.
Granitic intrusives (including the Matachewan porphyry).
Intrusive contact.
Timiskaming, Sudbury and Kiask series.
Unconformity.
"Keewatin" volcanics.

GEOLOGY OF THE GOLD DEPOSITS.

The township of Powell (Fig. 16) is roughly divisible into two parts, the southern, underlain by the Cobalt series, the northern by the older volcanics. The gold deposits lie near the contact of the two series, between the east and west branches of the Montreal river. Their situation with respect to this contact is purely fortuitous and without significance as regards their origin. The contact is in a shallow valley occupied in part by a small stream called Davidson creek. The valley was the temporary channel, after the recession of the glaciers, of a much larger, rapid stream, the west branch of the Montreal river, which has left its traces in the form of large pot holes at two or three places.

In Fig. 17 the geology of the gold deposits is shown. It will be seen that the old volcanics are cut by a series of intrusions of granite porphyry of varying size, and that these are arranged

along a fairly definite line striking N. 77 degrees E. This direction is approximately parallel to the axes of the folding of the older rocks, and probably represents some zone of weakness developed during folding. It seems also probable that the exposed portions of the porphyry may be only projecting knobs of a much larger body beneath. The porphyries and older rocks are cut by many large dikes of the basalt of the pre-Cobalt age, some of which are indicated. The Davidson discoveries were made on the westernmost body of porphyry, the Otisse discoveries in the schist adjacent to the largest body of intrusive.

On the Davidson claims, nos. 5371, 5372, 5374, 5375, and 5383 (Fig. 17) the ancient volcanics are greatly contorted and schistified, but have not been mineralized. Between the porphyry mass on claim 5372 and that on claim 5379 the schists are cut by many small dikes of porphyry, too small to show on the map, which indicate the unity of the two larger masses.

On the Colorado-Ontario claims, nos. 5379, 5380, and 5402, the volcanics, though closely folded, are not greatly contorted and but locally schistified. In the neighborhood of the mass of intrusive porphyry they are cut by dikes of porphyry and pegmatite and enriched by solutions depositing auriferous pyrite. The porphyry mass on these claims is the largest yet discovered in the district being somewhat over one-half mile in length and 500 to 600 feet in width. On its north side, trenching has exposed on claim 5380 an ancient schistose conglomerate. Claim no. 5402 is as yet undeveloped, and as it is heavily drift-covered, it was not closely examined. The geology of the other two claims, as far as development work already done enables it to be mapped, is partly shown in Fig. 18.

Volcanics.—The rocks of the volcanic complex (Fig. 18) include basalt on the south side of the claims, overlain by basalt tuff to the north, the latter in turn overlain by rhyolite tuff. The separation of these is difficult, so much so that it was found impossible to map separately the basalt and basalt tuff. The separation is of importance mainly for the determination of structure as ore bodies have been formed in all of them. Ore bodies are

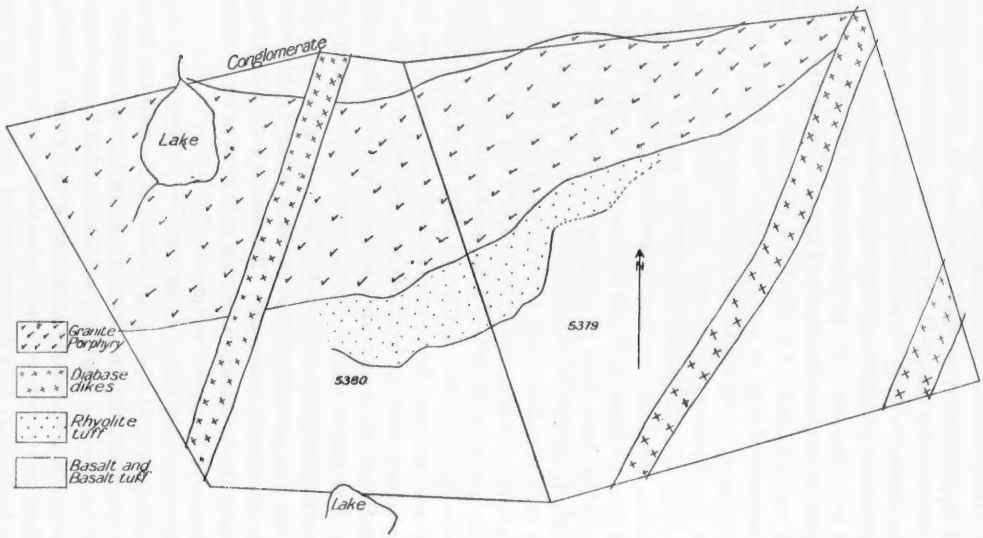


FIG. 18. Geology of property of Colorado Ontario Development Co., as shown by work done up to October, 1918.

largest and most numerous in the tuffs, but this may as well be ascribed to the fortuitous location of the tuffs nearest the intrusive as to a greater susceptibility of the tuffs to alteration and mineralization. The composition of these rocks will therefore not be minutely described, further than to say that they all consist entirely of secondary minerals. Chlorite and albite are the principal of these, with some free quartz in the tuffs, and accessory leucoxene, magnetite, pyrite and epidote in the basalts. Calcite in greater or less amount, secondary to and replacing the minerals mentioned, is invariably present.

Porphyry.—The porphyry which intrudes the ancient volcanics is a reddish, coarse-grained rock containing mainly orthoclase and albite, with some interstitial quartz and a little muscovite. A good deal of secondary calcite is commonly present. Chlorite forms a minor constituent, and iron pyrite in small crystals is accessory. The term "porphyry" is something of a misnomer, as porphyritic textures are not usually to be seen. An analysis of the porphyry[3] shows: SiO_2 61.80 per cent., Al_2O_3 18.86 per cent., Fe_2O_3 2.95 per cent., FeO 0.32 per cent., CaO 0.63 per cent., MgO 0.34 per cent., K_2O 8.86 per cent., Na_2O 3.19 per cent., H_2O 0.54 per cent., CO_2 0.84 per cent., FeS_2 1.45 per cent. Total 99.78 per cent. A calculation of the mineral composition from this analysis gives: Quartz 9.26 per cent., orthoclase 41.80 per cent., albite 27.13 per cent., muscovite 15.22 per cent., with small additional amounts of calcium and magnesium carbonates, pyrite and iron oxides. However, no such proportion of muscovite as this is observable in the specimen, and it is possible that the amount of water in the rock has been underestimated. A somewhat larger percentage of water would permit of the 3.94 per cent. of alumina present in excess of the requirements for determination of the alkalies as feldspar to be calculated as kaolin. The rock is remarkable for its high content of potash.

The surface of the porphyry is usually oxidized, in places, to a depth of 6 or 8 feet. This residual material is iron stained and commonly rich in free gold, especially on the Davidson claims.

[3] Burrows, A. G., Ont. Bur. Mine, Rep. 27, p. 227. 1918.

Pegmatites.—In the neighborhood of the porphyry mass on the Colorado-Ontario claims there are numerous dikes and veins intrusive into the older schists. They vary in size from dikes 10 feet or more in width down to small stringers. Their outcrops are lenticular in shape, their downward extension is not yet known. The larger usually conform in strike fairly closely to the strike of the rocks which enclose them, but the small veinlets have broken through the rocks in all directions. There is great variation in composition; the larger are in some cases identical in composition or almost so with the main mass of porphyry; others, the so-called "gray porphyry" of the miners, are more siliceous, but still highly feldspathic; others are true pegmatites. The smaller veins range in composition from pegmatites composed of about equal parts of quartz and feldspar to veins of pure quartz. The latter, however, are rarely over an inch or two in width, so far as observed.

The dikes and veins are all localized within a short distance of the main mass of porphyry; within 500 feet they are numerous, but the number becomes rapidly less with increasing distance. With a few exceptions all lie within a boundary drawn about 1,000 feet from the edge of the porphyry. Their localization, coupled with their composition relations, renders almost inevitable the conclusion that they are satellitic to the porphyry.

Diabases.—The diabase dikes which cut all the rocks so far described may have a magmatic connection with the porphyry. In composition they are ordinary quartz diabases, consisting mainly of labradorite and pyroxene with a small amount of an interstitital intergrowth of quartz and albite. The rocks appear fresh in the hand specimen, but under the microscope the feldspar is seen to be much altered to an intergrowth of kaolin and sericite or paragonite. In places the dikes are highly porphyritic, with phenocrysts of labradorite up to 3 and 4 inches in diameter. The phenocrysts are invariably almost completely altered to kaolin and sericite. A careful examination was made to determine whether the dikes had been intruded along planes of faulting, but no lateral displacement of the rocks on either side could

be determined. On claim 5383 (Fig. 17) the Cobalt conglomerate may be seen lying on the eroded surface of the diabase and including boulders of it. The only connection of the dikes with the porphyry, is their localization. They are numerous in the vicinity of the porphyry masses, and are also occasionally found cutting the feldspathic granite to the south to which, on account of its mineralogical and chemical similarities, the porphyry is supposed to be satellitic. Outside of these occurrences the dikes have nowhere been observed during a recent exploration covering about 300 square miles of adjoining territory.

Structure.—The structure of the basement volcanics on the Colorado-Ontario claims was carefully studied. Grain determination made by methods described by the writer in a paper now in course of publication in the *Journal of Geology* indicated that the rocks form a portion of the south side of a tightly folded syncline, so that the basalts are the lower rocks in the series, the rhyolite tuffs the higher. The conclusion was strengthened by the later discovery of an ancient conglomerate on the north side of the mass of intrusive porphyry and also by good structure determinations made on the volcanics on the shore of Mistinigon lake, about 2 miles due west, where the structure is similar and the axes of the folds have a general east-west strike.

The map showing the boundaries of the mass of rhyolite tuff so far as exposed on the claims suggests that the fold here is a canoe, with anticlinal cross folds to the east and west. However, the mapping is so incomplete owing to the lack of sufficient trenching, that it is difficult to draw definite conclusions.

Preliminary drilling has brought out the fact that the boundary between the rhyolite tuffs and the underlying basalt tuffs dips to the south at a high angle. The fold is therefore slightly overturned at this point. The folding evidently took place before the intrusion of the porphyry, as the porphyry is not sheared even in the small satellitic dikes.

The bedding appears to have determined in part the intrusion both of the main masses of porphyry and of the satellitic dikes and veins. The long axes of the larger masses of porphyry are

parallel to the main axis of folding of the older rocks, and the linear arrangement of all the masses points to the original presence of some line of weakness, probably developed during folding. The larger dikes and veins are in general parallel to the bedding, although in places they break across it. Since the ore bodies, as will be shown, are peripheral to the dikes and veins, a knowledge of this arrangement is important in the prosecution of the search for ore.

DESCRIPTION OF THE ORE BODIES.

Davidson Type.—On the Davidson claims the ore body is a portion of the porphyry itself. The porphyry is cut by a multitude of veinlets of auriferous quartz mostly less than one quarter inch in thickness, and spaced at intervals of approximately a foot. The porphyry has thus the character of a stockwork, although the veins in the main are not reticulating, but possess a subparallel arrangement evidently the result of jointing according to a definite system. Such jointing and enrichment has taken place mainly in the coarser-grained, more slowly crystallized phases, located, in general, toward the centre of the intrusive. Where the grain is finer, jointing and enrichment has not occurred. The hypothesis advanced by Spurr,[4] that the last portions of a magma to crystallize are rich in water, and hence must contract considerably on cooling with formation of joint cracks, may be the explanation of this phenomenon.

Channel samples taken along the bottoms of trenches in the enriched areas by the engineers examining the property are said to have yielded values varying from $5 to $25 per ton.

The gold appears to be chiefly present as the native metal, although it is difficult to tell whether this was its original form, as development has not gone below the oxidized zone. However the lack of limonite around many of the grains of gold would indicate that it is not residual from the oxidation of pyrite. Whether the pyrite also is auriferous has not as yet been established. The gold is found principally in the narrow veins

[4] Spurr, U. S. Geol. Surv., Prof. Paper 55, p. 114.

of quartz that intersect the porphyry, but grains of gold have occasionally been found within the porphyry itself, although never more than a few inches from a veinlet. It is evident therefore that the gold was introduced by the solutions which also deposited the quartz.

Otisse Type.—On the Colorado-Ontario claims the porphyry has not been enriched as on the Davidson claims, so far as known at present, but a heavy cover of soil and swamp on it has hindered prospecting. Those portions which have been uncovered, are jointed and veined only to a slight extent. The ore bodies of this property are found in the schists surrounding the intrusive. Little is known as yet about the nature of the ore bodies beyond what can be seen on the surface, as drilling had not been carried far enough at the time of examination to show with certainty the connection of the subsurface ore bodies with the surface ores. Many of the statements here made will probably therefore have to be revised at a later date.

The schist ore bodies are lenticular. While this has been proved in only two cases by the removal of the drift from the whole outcrop of the ore body (namely those at the south ends of trenches 8 and 9, Fig. 19), the fact that ore bodies crossed by a trench can rarely be picked up in a parallel trench 50 or 100 feet distant, indicates a similar shape for these also. Drilling is at present being conducted with the object of testing the hypothesis that the lenticular outcrops are but the surface expression of ore shoots which may have a considerable downward extension. The size of the ore bodies varies greatly; small bodies a few inches or feet in width are numerous, while the largest so far found is about 75 feet in width. The large bodies lie with their long axes approximately parallel to the bedding planes of the tuffs, and may eventually prove to have some relation to the secondary folding. The position of the smallest bodies, those in general less than a foot in width, does not seem to have been controlled by the bedding, but by joint cracks, so that they lie in various positions.

The internal structure of the ore bodies of the Otisse type

is indicative of their origin. Fig. 20 shows on a large scale one such ore body about 12 feet in width, occurring in trench No. 1. At the centre there is a body of rather siliceous pegmatite about 3 feet in width measured along the trench; on each

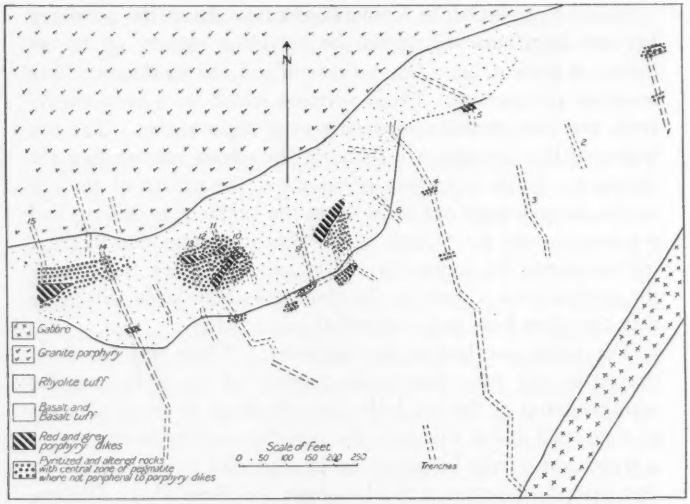

N
Gabbro
Granite porphyry
Rhyolite tuff
Basalt and Basalt tuff
Red and grey porphyry dikes
Pyritized and altered rocks with central zone of pegmatite where not peripheral to porphyry dikes
Scale of Feet
0 50 100 150 200 250
Trenches

FIG. 19. Sketch map of the portions of claims 5379 and 5380 where the principal discoveries have been made.

side a band of altered and mineralized rock, about 3 feet wide on the south side and 1½ feet wide on the north side. The alteration, which will be described more fully later, consists mainly of calcitization. The mineralization consists of pyrite, usually auriferous. An outer zone of rock, altered but not mineralized, flanks the altered and mineralized zone; this is 6 feet wide on the north side, and slightly less than a foot on the south. The light grey, altered rock grades into the dark green country rock in a short distance, but without any sharp boundary line. The gradational zone is commonly an inch or two in width. The line of contact is wavy, and frequently embayed in a highly irregular manner.

The structure described is characteristic of all the ore bodies in the schist, although it is sometimes rendered more complex by the intrusion of two or more veins of pegmatite within each other's zone of influence, or its recognition may be obscured by an insufficient development which exposed only ore without the

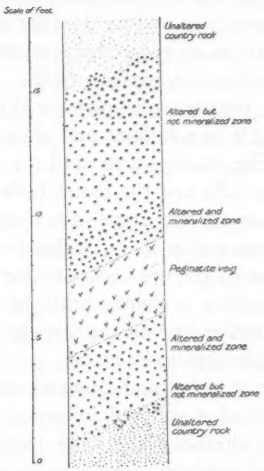


FIG. 20. Sketch showing internal structure of ore body uncovered in no. 1 trench.

central pegmatite. Variations occur in the composition of the central dike or vein, the width of both inner and outer zones of alteration, and the extent of the enrichment of the inner zone and the alteration in both. The data so far secured are not sufficient to determine the relation between these variations, but enough has been done to indicate that the composition and size of the central dike or vein are the principal governing factors, while there is also a possibility that some of the country rocks may have been more easily altered than others.

The data bearing on possible differences in susceptibility to alteration in the country rocks are scanty. All of the volcanics

are seen under the microscope to be similar in composition, their differences being mainly in the relative proportions of the constituent minerals. If one rock is more susceptible to alteration than another, it cannot be due to difference in composition, and the cause must be sought in physical differences, such as texture. The tuffaceous types, the rhyolite and basalt tuffs, undoubtedly had originally a more open texture than the massive basalts; and when sheared, their lesser competency resulted in their becoming more schistose than the massive rocks. Both their original texture and their greater subsequent schistosity would make them more permeable to solutions, and allow of a larger degree of alteration. As Fig. 19 shows, most of the ore bodies are localized in the rhyolite tuffs and the basalt tuffs which directly underlie them. However, the fortuitous location of these tuffs next to the intrusive makes it impossible to conclude definitely that the localization of the ore bodies is due to the influence of the country rock and not to chance, until the development operations are carried further around the boundaries of the intrusive so as to allow comparisons to be made.

Data connecting the size and composition of the veins and dikes with the width of the altered zones and the intensity of the mineralization and alteration are more plentiful, but not complete. Dikes of red porphyry, whose composition is closely that of the main body of intrusives, have had little effect on the country rock. These may be seen (Fig. 19) in trenches 5, 7, 14. Occasionally they have caused a small amount of pyritization in the wall rock, but never any visible alteration. An exception is the dike cutting trench No. 15. Flanking this dike is a wide zone heavily mineralized with coarse-grained pyrites, but the country rock is slightly, if at all, altered, while the pyrite, unlike that in other ore bodies, has a very small gold content.

Two dikes of what the miners term "gray porphyry" are exposed by trenches 10–13 (Fig. 19). The outcrops of these dikes, which are lens-shaped, are about 100 feet long and 10 to 20 feet wide. In their composition they are intermediate between a pegmatite and the red porphyry. The amount of feldspar present

is so high that they would unhesitatingly be classed as igneous rocks in the field or from the hand specimen, but under the microscope they are seen to be considerably more siliceous than the red porphyry. Alteration of the feldspar to calcite has taken place. The dikes contain sufficient auriferous pyrite to yield gold values varying from $3 to $50 per ton, with an average of about $10. The rhyolite tuff around and between the dikes has been only slightly altered, but has been somewhat pyritized over a distance varying from 10 to 25 feet from the dikes. The tenor however is low, on the whole $2 per ton or less, although occasionally a high assay has been obtained, due no doubt to the accidental inclusion of a locally enriched portion in the specimen taken.

The ore body indicated in Fig. 19 at the south end of trenches 7 and 8, has as its center a vein of pegmatite about 4 feet in width. This pegmatite is now much weathered, but can still be seen to have been highly feldspathic, probably about 40 to 50 per cent. feldspar, the remainder mainly quartz. The vein lies parallel to the bedding and the mineralized and altered zone is approximately 12 to 15 feet in width on the southeast side, and 7 or 8 feet on the northwest side. Beyond the mineralized zone the rock is altered with but slight mineralization for 3 or 4 feet further. The gold content in this lens of ore is among the best on the property, averaging from $12 to $15 per ton. The alteration in the mineralized and altered portions has been intense, fully 75 per cent. of the rock having been replaced by calcite in the portions nearer the central vein of pegmatite.

Fig. 20 also illustrates the general extent of the alteration and mineralization induced by a pegmatite containing about 8 per cent of feldspar. It will be observed that although the central vein averages nearly as wide as in the example just described, the total width of the mineralized zones on both sides of the vein is only 4½ feet, as opposed to 18–20 feet. The total width of altered rock with and without mineralization is only about 12 feet, as opposed to 25 feet or more. The gold content in the two cases appear to be about the same, while the intensity of alteration to calcite is slightly less.

In trenches Nos. 3 and 4, among others, narrow veinlets both of pegmatite and quartz may be seen. The quartz veinlets are never more than about an inch thick. In trench 3 a pegmatite veinlet one quarter to one half inch in width is surrounded by a mineralized and altered zone about 2 feet in width. The pegmatite is about 30 per cent. feldspar. The mineralization is fairly heavy, sufficiently so to give about $10 per ton. In trench No. 4 a similar narrow vein of pegmatite was observed, whose feldspar content is confined to a few small crystals along the wall of the vein. Alteration extends only about 2 inches from the walls, and mineralization is comparatively small. In the same trench a veinlet of quartz was observed, about an inch in width. On each side of it the rock is altered for a distance of about a foot, but the mineralization has been slight.

The facts described appear to justify the following conclusions: (1) The ore bodies have been formed by solutions emanating from the dike or vein at their centers. These solutions have altered and mineralized the country rocks. (2) The tuffs may have been more easily altered and mineralized than the altered basalts. (3) The extent of the mineralization and alteration are related to the size and the composition of the central dike or vein. The strongest alterative and pyritizing effects have been exercised by the pegmatites, while the the effects of the end members of the series, the porphyry dikes and the quartz veins, have been slight. The pegmatites containing 25–50 per cent. of feldspar appear to have produced the most powerful mineralization and alteration. Other things being equal, the extent of alteration and mineralization is roughly proportional to the size of the dike or vein. (4) The gold content of the dike and vein-forming solutions was also dependent on their composition. The pyrite deposited by the dikes of red porphyry contains relatively little gold. Gray porphyry dikes carried more gold, sufficient to give a good tenor within the dikes themselves, but not, apparently, to mineralize the surrounding rocks to any great extent. Pegmatites appear to have carried the maximum of gold, which they deposited as auriferous pyrite both in the veins and

in the altered wall rocks; while the solutions forming the pure quartz veins carried little gold.

The only primary ore mineral present appears to be auriferous pyrite; however, a detailed study of the ores by the aid of the reflecting microscope has not as yet been made. If ore minerals other than pyrite are present, they are in minor amount. The gold occurs only in the pyrite, in what form is not known. Native gold is not found, except in oxidized surficial portions. In general a high pyrite content indicates a correspondingly high gold value, although in one or two places this has not proved true. In the pegmatites the pyrite is coarse-grained, in crystals and aggregates several mm. in diameter; but in the adjacent schists the pyrite is always fine-grained, 0.3–0.5 mm. in diameter of crystal. Only in one case was this not found to hold good—in the ore body in trenches 14 and 15 peripheral to the dike or red porphyry in 15. There, the pyrite is very coarse-grained.

The wall rock alteration accompanying the mineralization produces a rather light gray, fine-grained rock from whatever variety of rock has been originally present. Under the microscope the alteration of the portions farthest from the central vein is seen to consist of calcitization, pyritization and sericitization, with probably some albitization. Fine-grained magnetite originally present in the altered basalts in amount up to 5 per cent. is converted into sulphide, forming a few crystals up to 0.5 mm. diameter instead of a multitude of small grains. Possibly also some pyrite may be added. Feldspar, which is commonly oligoclase-albite either lath-like or irregular in shape, is entirely recrystallized into a fresh, clear, granular albite, with possibly a slight increase in soda content. Chlorite disappears entirely, while 10–15 per cent. of sericite is formed, and calcite, commonly forming 10–20 per cent. of the original rock, is increased in amount to 40 to 50 per cent. Nearer the central vein, under the more intensive action of the solutions, further changes take place. Albite and sericite tend to disappear entirely; a great addition of pyrite occurs, while the calcite content increases enormously, and may replace everything but the pyrite. A little

quartz is sometimes present, but always in vague vein-like forms, and not a part of the true replacement. The pegmatite of the central vein itself also has very commonly suffered a partial alteration, in a replacement of a part of its feldspar by calcite.

The composition of the solutions which deposited the ores may be inferred from the results of their action on the country rocks. They were evidently rich in sulphur, and also carried iron. A great deal of carbon dioxide was present, and the lime content was high. They carried potash and soda, but probably only in small amount. They dissolved and removed silica, alumina, and magnesia primarily, while potash and soda were also carried away where the reaction was more intense, nearer the central veins.

SUMMARY AND CONCLUSIONS.

1. The internal structure of the ore bodies, consisting of a pegmatite vein at the center, a middle zone of mineralized and altered rock, on each side, and an outer zone of altered rock without mineralization, which grades into unaltered country rock with irregular and embayed contacts, is clear evidence that the deposits in schist have been formed by the alteration and mineralization of the country rock by solutions coming up along the central vein. The partial calcitization of the feldspar of the pegmatite indicates a change in the character of the solutions during the formation of the ore bodies.

2. The serial composition of the various veins of pegmatite, varying from veins of pure quartz up through pegmatites of increasing feldspar content, to dikes of pure porphyry, indicates an igneous origin for all.

3. The satellitic arrangement of the veins, in that with few exceptions they are grouped within an area bounded by a line drawn about 1,000 feet from the edge of the porphyry mass, with the major number within 500 feet, points conclusively to their genetic connection with the porphyry intrusive.

4. Veins or dikes approaching the porphyry in composition, deposited little or no gold, but did in places deposit pyrite. They had no strong alterative action on the wall rocks. Pegmatites

deposited auriferous pyrite, and had a powerful alterative action on the wall rocks. Quartz veins had little action on the wall rocks, and deposited little or no pyrite. Other things being equal a rough proportion exists between the size of the vein and the size of the altered zone around it.

5. It is concluded, therefore, that the schist ores of the Matachewan district were deposited by juvenile solutions originating as the last products of the differentiation of masses of intrusive granite porphyry. The solutions were at first rich in silica, soda and alumina, which crystallized out first to form the material of pegmatite veins. The separation of these constituents left the solutions relatively enriched in lime, carbon dioxide, iron, sulphur, potash, and gold, and their reactions with the wall rocks caused the formation of replacement deposits whose principal minerals are calcite and auriferous pyrite.

6. There is little direct evidence to connect the gold of the Davidson property with the porphyry, except the fact that the veins are confined within the intrusive mass. However, the proof that the neighboring stock, which is petrographically identical with the Davidson porphyry, carried gold, renders the conclusion inevitable that the gold of the Davidson property was also a magmatic constituent. The differentiation has here continued uninterrupted to the stage in which the mineral constituents of the magmatic solutions are silica and gold, and these are deposited as quartz with native gold.

OBSERVATIONS ON A FLORIDA SEA-BEACH WITH REFERENCE TO OIL GEOLOGY.

J. F. KEMP.

INTRODUCTION.

The subject of beach sands as representing old shore-lines is now one of much interest, in connection with oil geology. In the Mid-Continent and in the Appalachian fields geologists are seeking to reproduce in their minds the physiographic and geologic conditions prevailing at the time of deposition with the purpose of interpreting the lenticles or longer stretches of sandstones which are today the reservoirs of oil and gas. Sea-beaches, especially where subject to the play of surf and to shore currents, furnish one of the most favorable situations for the accumulation of coarse, mechanical sediments and thus for possible ultimate reservoirs for the hydrocarbons. The sea-beaches in their large relations are also of interest in connection with the general interpretation of sedimentary beds and the physiographic relations of shore-lines.

Enforced cessation of all customary occupations compelled the writer to spend the months November to May of 1915–16 and November to March of 1916–17 at Melbourne Beach, Florida, a little winter resort on the Atlantic Ocean about midway of the peninsula from north to south. The first season a cottage was occupied on the beach just above the limit of the highest surf at times of storm. Almost all the fair days were passed in the open air on the beach. Much of the time, when conditions were suitable, was employed in fishing in the surf, along two or three miles of the shore. The second season, the time was spent in the same manner. Inevitably, in this way, and by surf bathing, walks along the beach and the Indian River, opportunity was afforded for a very intimate observation, not alone of the ocean beach itself, above low-water mark, but also of the ocean bottom, out

to the off-shore bar, and even beyond. A skilful angler casts a sinker of 4 to 6 ounces of lead 40 to 60 yards into the ocean, many times during the day, and comes to fairly feel the character of the bottom.

Opposite Melbourne, on the mainland of Florida, the brackish lagoon called the Indian River is from two to two and one half miles wide. It reaches a maximum depth of fifteen to twenty feet, but as a rule is much shallower and has sand-bars which jut out long distances, especially from its eastern shore. From the ocean Indian River is separated by a strip of sandy land about a half mile wide and rising to a maximum height of about fifteen feet above the water on either side. Old residents stated that the U. S. Engineers had determined the mean level of the river as one foot above the mean level of the ocean. There is no outlet to the ocean for forty miles in either direction from Melbourne. The surface of the strip is not level, but varies between small ridges, doubtless in the nature of sand dunes, and intervening hollows, locally called savannas. All the rainfall sinks into the sand; there is no visible run-off, nor are there any erosion channels except from wind action. The shore-line on the west is a series of points and bays, but on the ocean-side it is almost if not quite straight and runs a few degrees west of north. About forty miles north is Cape Canaveral, with a tall lighthouse, whose light we could detect on clear nights, apparently well out to sea, although the lighthouse is itself two miles inland. The shore, south of Cape Canaveral, thus swings away to the west, but some distance north of Melbourne Beach it turns to the southeast. On account of the jutting of a long reef out from Cape Canaveral to the southeast, ocean traffic keeps well off-shore and first turns in near the Florida coast at Jupiter Inlet and lighthouse—fifty miles or more south of Melbourne Beach.

The greater part of the sandy strip is covered with saw palmettos (*Serenoa serrulata* (Mich.) Hook), a dwarf variety whose trunks lie prone and at the end send upward for four or five feet a group of stout palm leaves. With the palmettos are associated scrub oaks, sea grape, smilax, bay-berry and rarer,

usually thorny shrubs, making an almost impenetrable growth, except where artificial or natural trails run across (Plate V., *a*). On the Indian River side, are occasional woods of pitch pine, and of oaks. Orange groves have also been planted and they and grape-fruit trees can be cultivated as well as pineapples and other fruits.

Beneath the surface potable water is tapped everywhere by drive wells at a general depth reputed to be fourteen feet, but the water is hard. The water level is presumably that of the Indian River or of the ocean. The hard nature is due to the fact that in the deposition of the sand along the ocean beach many fragments of shells are included with the predominant quartz sands. The calcareous fragments pass into solution in the descending rain-waters. Away from the active deposition of the ocean strand, or of the Indian River shore, the sand is chiefly fragments of quartz, with a little admixture of vegetable matter. On the surface the sand is grayish-white, but just below it is yellow and iron-stained in the section of a foot or more, containing the ordinary roots of vegetation. Piles heaped up by small burrowing animals are yellow. When a sample of the yellow sand is treated with dilute hydrochloric acid the yellow color disappears entirely and the solution gives a reaction for iron. The amount of iron oxide was roughly estimated at less than one per cent. The sand gave no effervescence on treatment with acid and was free from calcium carbonate.

Artesian well-borings show that beneath the surface sands there are contrasted rocks. The record of a well about three quarters of a mile north of Melbourne Beach and fifty feet from the Indian River is as follows:[1]

Surface sands and soil	0– 3	Dark-colored rock with sharks' teeth	173 –173.5
Yellow sand	3– 11	Greenish clay	173.5 –174.25
Coquina rock	11– 21	Dark-colored rock with sharks' teeth	174.25–175
Fine gray sand	21– 51	Greenish clay	175 –221
Shell and sand	51– 56	Vicksburg limestone ..	221 –318
Hard shell rock	56–119		
Greenish clay	119–173		

[1] Recorded by the owner, the late Mr. Gibbs, and forwarded to the State Geologist, Dr. E. H. Sellards, who published it in his Third Annual Report, p. 188.

In the wells of the region, sharks teeth are very generally met at the horizon above noted. One was given the writer by a local driller, and has been determined by Dr. J. J. Galloway to be *Galeocerdo aduncus* Ag., a Miocene species. Sulphurous water was tapped in the Gibbs well in the Vicksburg limestone at 221 ft. and increased in flow as the well deepened. At 318 ft. it gave a pressure at the surface of 17.5 lbs. per square inch. Many other wells have been drilled in the mainland and the general experience is to strike the sulphurous water at about this depth and to find it under pressures similar to the one given. Despite the absence of any notable height of land for two hundred miles or more, the water flows out under a good head, and is serviceable for irrigating orange groves for many miles around Melbourne.

In describing the phenomena of the ocean beach, we may divide the subject into two parts, the materials which make it up, and the topographic forms which these materials assume.

THE MATERIALS OF THE LAND.

The sand consists chiefly of fragments of quartz. With these are varying amounts of shells or bits of the hard, calcareous parts of other organisms. Sometimes the calcareous fragments predominate, but as a rule they are much less in amount than are the fragments of quartz. There are many other minor constituents of which additional notes will be given below. They embrace bits of coal and cinder from ocean steamers, bits of bottle-glass; large and small fragments of wood; a little magnetite; and from one sample a quite extraordinary proportion of tiny zircons.

Samples were taken as follows: No. 1, ordinary beach sand above high-water mark, except in time of storms. No. 2, a second sample like No. 1. No. 3, a thin, dark layer exposed by a strong north gale.

Under the microscope in No. 1 the most abundant component was quartz in grains up to 0.4 mm. Many were water-worn and had the aspect of ground glass, but some were still surprisingly angular and sharp, when one considers that the nearest point at

which a river enters the ocean after draining a region of quartz-bearing rocks, is more than 200 miles to the north. Almost all the remainder of the sample consisted of shell fragments, ranging in size up to 2 or 3 mm. A stray bit of water-worn coal was the only other component.

Sample No. 2 was much the same as No. 1 and both present a very fair representation of the sand which makes up the land above the reach of the waves, but which has not been leached of its soluble components. On partial analysis of each sample, the following results were obtained and with them is placed No. 3, which is more interesting in its mineralogy.

	No. 1.	No. 2.	No. 3.
$CaCO_3$	37.00	31.85	18.80
Mixed insolubles, chiefly quartz	59.62	66.15	78.52
Total	96.62	98.00	97.32

The lime was determined by dissolving in weak hydrochloric, precipitating as oxalate and titrating the oxalate with permanganate solution. The insolubles were caught on the filter, ignited and weighed. They were white and in the first two were apparently all quartz. The missing per cents. are undoubtedly magnesium carbonate, magnetite and fragments of coal. The results make clear the fact that until leached by the rain-waters, the beach sands along this part of the Florida coast would yield a highly calcareous sandstone, doubtless with streaks of purer siliceous sand, and with rare beds of the mineralogy of No. 3. The last-named was a sample of a darker and heavier layer, exposed by a strong gale, which had blown away the lighter components. It was above the reach of the normal surf. Its dark color attracted attention. Besides the predominating grains of quartz and fragments of shells, small, well-crystallized zircons were common. Grains of magnetite, coal, garnet, epidote and a brown, isotropic substance, believed to be bottle glass, complete the list. In another similar sample gathered at a different place and time, colorless, as well as yellow and brownish zircons are

extraordinarily abundant and range in long dimension up to 0.3 mm. Granitic rocks must have supplied these grains, and the probable source is the old crystalline rocks of the states draining into the Atlantic, but to what extent they have temporarily rested in sandstones no one can say.

Minor Phenomena of the Beach.—The phenomena of the beach constantly remind an observer of the features displayed by quarries in sandstone such as the Medina sandstone near Lockport, New York. Each breaker as it sweeps up the beach leaves at the upper limit reached by it a little ridge of sand, which remains until effaced by the next roller. As the tide falls the wetted beach dries and a thin and very tender crust is caused by the salts in the evaporated sea-water. One often notices slight blisters in the sand exposed in this way. They are two or three inches in diameter and bulge up a quarter or half inch above the general level. Their explanation was a puzzle until it was discovered that beneath each was one of the breathing holes left by the organisms which live in the sand. A breaking wave, usually the last high roller of a particular tide, dashes in with a pounding and sweeping action, compresses the air in the hole and covers the opening with a film of wet sand. On its retreat the air expands and lifts up the layer of wet sand just a trifle. The sun dries out the water, leaving the salts as a weak cement to hold together the grains.

At times of strong wind, usually from the north, the sand is blown along in such quantities as to severely sting the face and hands when one walks against it. Wind ripples are produced with convex sides uppermost and shaped like a slightly overturned anticline with sharp and relatively narrow depressions between them. The largest were about three inches across, and customarily showed a slight crust from the salts left by evaporation under the influence of the wind. Were the gale succeeded by very quiet conditions, as might easily happen in the spring and summer, water ripple-marks with sharp ridges and relatively broad valleys might form beneath the sea a few yards away. Subsidence could conceivably cause both to be buried and

preserved in fairly close association. Stranded shells between the upper and lower limits of the surf produced rill-marks of great perfection.

The sand of the beach above and for some distance below the limit reached by the surf at high tide is soft and makes walking tiresome. But for about five yards above the limit attained at low tide under conditions of ordinary surf the sand is hard when exposed and is scarcely dented by the heels of shoes. One could ride a bicycle with entire comfort. Farther north at Daytona the beach has a very flat slope and is a famous racing and pleasure course for automobiles. The exact cause of this solid packing is hard to discover. It may in some way be due to the pounding of the breaking waves at the place of greatest violence. The same packed character is possessed by the off-shore bar. At times from this hard, smooth sand and the instant a retreating wave exposed it, thousands of a little lamellibranch, *Donax variabilis,* Say, would pop out with their gills in the air, instantaneously, as if from a word of command. When the next wave rolled in and before it could sweep them up the beach, they all "dug in" out of sight, with the same instantaneous precision. They are called "coquina clams" and may be gathered like so many berries when they pop up, and also be obtained when they do not pop out of themselves, by digging the sand with a shovel and filling a box whose bottom is quarter inch wire screening. The sand can be washed through in the next wave and the so-called clams be caught on the screen. Many little crustaceans, called "sand fleas" are also entrapped and are used for bait in the Indian River fishing. Together these two creatures must contribute an important amount of organic matter to an apparently barren sand. Whether if interred by relatively quick subsidence and sedimentation they might contribute to petroleum and natural gas is a fair question. Rarely a *Donax* is caught unawares by an oncoming wave and washed up where the sand is too dry for it to dig in. Then it dies and is mingled with the beach flotsam and jetsam.

Although the hard sand with its organisms is usually to be ob-

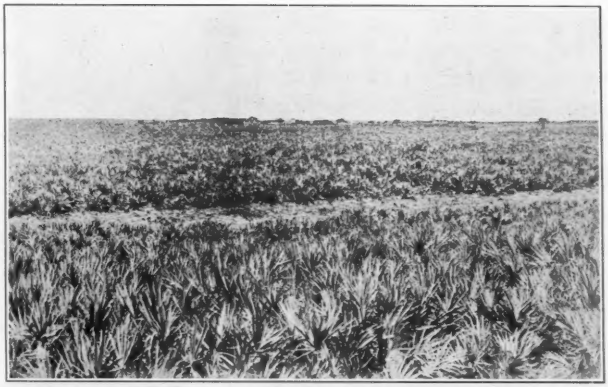
served as described, the experience is not invariable. Under certain conditions which the writer did not positively identify as compared with the normal ones, the portion of the beach which is hard at other times, becomes slushy and soft. It is very uncomfortable to walk upon, and when dug and washed it scarcely yields a *Donax*. The slushy sand is coarser than the hard packed variety and contains a large proportion of fragments of shells. The writer finally concluded that the layer of sand, when packed, was about 4 to 6 inches deep, and that it rested on the coarse, slushy variety which would not pack. If the surf washed away the finer quartz sand, the coarser, slushy variety would be exposed, but what became of the sometimes multitudinous *Donax* was not discovered. Whether they dug down and waited for the sand to come back, or whether they went off into deeper water, is hard to say; but when conditions had changed and the finer, hard-packing sand had come back, of a sudden many thousands would again pop out. The *Donax* when in the sand stands across the bedding and if buried in the natural position would yield a fossil perpendicular to the stratification. The individuals stranded by the waves where they could not dig in, would be parallel to the bedding. The stranded shells in their relations to the sediments constantly reminded one of the *Lingulas* to be collected in the Medina sandstone, such as the exposures near Lockport, New York, already mentioned. The chief point of interest in connection with oil-geology lies in the great numbers of organisms which may live in the sand above low-tide level and which could be easily interred by a change of conditions, and which might escape the notice of an observer on the beach nine days out of ten.

The only other organism worthy of note which lived in the sand was a burrowing crab which made its home above high-water mark and dug a circular hole two or three inches in diameter. Although not always so deep, yet the writer has often pushed a stick four or five feet down in the almost vertical hole without meeting an obstruction. The crabs heap up a small pile of sand at the entrance to their burrows, and as they run on the

sharp ends of their rather long legs they leave many tracks in the sand nearby. The tracks if preserved would make very puzzling fossil records. The crabs are chiefly active at night and may be caught with the aid of a lantern or electric torch, being a serviceable bait for bass. They run for the sea when surprised away from their burrows in the daytime. If buried in their burrows and fossilized they would afford a crustacean in the midst of coarse, mechanical sediments.

Clots of Asphalt.—Several times during the first winter the beach was found to be dotted with clots of soft asphalt, quite thoroughly mingled with sand. It was so disguised by the sand as to be first noted by sea bathers who innocently stepped on the clots in going to and from the water. On their first appearance the clots were most numerous and the writer walked the beach for a couple of miles in each direction, being impressed with the fact that they grew fewer both to the north and the south of the settlement. They were too heavy to float and consequently appeared to have been washed up by the sea. One would infer that some sort of asphaltic spring or exudation exists on the sea-bottom not so far from the shore as to be in sufficiently deep water to escape the agitation produced by a strong wind. One can hardly believe that these clots have come from known asphaltic sources in Cuba or elsewhere in the Caribbean Sea. They appeared at intervals of a month or so three times during the first winter, but were scarcely seen at all during the second. When warmed the asphalt melted to a deep brown, viscous liquid with a slight petroleum odor. A sample has been saved.

There has been much interest in drilling for oil farther north in Florida, and the chance remark of the writer that the asphalt was oil-sign got into print and led to some local interest, but so far as known to him the clots of asphalt, and perhaps the sulphur water obtained all over this section at 200–250 ft. are the chief tangible bases for the local interest. The whole country is covered with the recent sands or with muck in the swampy areas. The surface has very slight relief. The only data for structure would be the shallow artesian wells, to the limey stratum that



a

FIG. *a*. Looking from ocean toward Indian River, showing thick growth of dwarf palmettoes which would supply in the event of submergence, abundant and resistant materials for fossil plants.

b

FIG. *b*. Cross-section of a shell-mound, in which the stratified structure from the blackened remains of ancient fires may be seen.

a

FIG. *a*. A flat beach without cusps.

b

FIG. *b*. The beginnings of cusps during an easterly gale, with high surf. The waves break first on the outer bar, and a second time on the shore beach. Viewpoint identical with Fig. *a*.

yields the sulphur water. Could accurate records be obtained and plotted some idea of the behavior of this particular bed might be gained. The clots of asphalt if ultimately buried in the sands and involved in future rock would give local spots of black, carbonaceous matter, not easy for a future stratigrapher to explain. They may provide a suggestion to present-day workers regarding similar puzzles in sandstones now exposed to study.

The Shell-Mound.—A quarter of a mile north of Melbourne Beach Landing on the shore of the Indian River is a shell-mound or kitchen-midden, of impressive size although not as large as others known elsewhere in Florida. At its southern end the mound has been quite extensively dug for road-metal, to which purpose the partially fossilized shells are well adapted. Good sections are thus afforded. The shells rest on the ordinary sand and begin about five feet above the level of Indian River and a few feet back from the shore. The mound is fifty feet or more across at the base, and thirteen feet thick. It extends, as roughly estimated, about a thousand feet north, in form like a railway embankment and except for the path along its top is covered by a thick growth of small trees and bushes. It gradually becomes thinner at the north end and finally dies out. The shells are distinctly stratified because of layers of thin, black, carbonaceous earth, undoubtedly the remains of fires in which the molluscs were cooked by the aborigines. The commonest species is a ribbed clam—*Venus cancellata,* Linn.—now thought to be extinct in the Indian River by the residents. With it are fewer members of a large, thick-shelled variety of *Venus mercenaria,* and the whelk *Sycotypus pyrum,* Lam. Bits of pottery can also be picked up in the excavation, but none were actually noted interstratified with the shells. The common criticism about the authenticity of such human remains, as to whether they tumbled in from the surface or were buried in the shells, cannot be met by actual personal observation, but the writer's belief is that they are buried up with the shells. A photograph of the end of the shell-mound is shown in Plate V. *b.* The great numbers of the shells in a mound of even moderate size, as this present one,

almost staggers one's belief in their accumulation from aboriginal feasts, but there is no other reasonable explanation.

Four or five miles north of Melbourne Beach, at the new settlement called Indialantic, there is another mound; and two miles south of Melbourne Beach on the next point there is a small one, about 3 ft. thick and 75 ft. or more long. If ever buried in a stratigraphic series, the mounds would yield very puzzling lenticles of fossiliferous limestone, but are so recent as to give no help in the interpretation of limestones in strata already consolidated.

The Topography of the Beach.

In this topic the word "beach" is used in its general significance for the strip of land which fronts the ocean and for the bottom along the shore to a point beyond the off-shore bar. At its landward extremity there is found for miles in either direction and doubtless along the coast in general a ridge, presumably an early sand-dune. The top of the ridge is about fifteen feet above low water. Away from the ocean it slopes gently down to a depression or savanna, but toward the ocean it presents an abrupt bank, eight or ten feet high, standing at the angle of repose of about 35 degrees. To a greater or less degree it is covered by grasses and other plants characteristic of the ocean shore. At its foot is often a slight hollow, bounded by a little ridge, a foot or less high, beyond which the surface slopes down beneath the waves in normal conditions at an angle of about 5 degrees. The stretch of sand before the water is reached is 75–100 feet across and has this uniform width for many miles along the coast. The bank undoubtedly marks the limit reached by the surf in very violent easterly gales, and is really a wave-cut terrace.

If submergence were to take place so that the beach sands would be buried and become rock, the resulting strata would obviously start with an initial dip (to adopt the expressive term of Bailey Willis[2]) of five degrees. The bank just described would doubtless be levelled off by the waves during submergence and

[2] 13th Ann. Rep. U. S. Geol. Survey, Part 2, 253, 1893.

the savannas and ridges would be obliterated, but the initial dip of five degrees would survive. Should such sandstones become involved in a relatively flat series of beds such as now constitute the Mid-Continent oil-field, extremely misleading structure would be afforded. Should the ultimate general inclination of the later flat beds be one degree in a direction opposite to the position of the ocean at time of deposition, an apparent and widespread reversal, not at all associated with anticlines, would result. After the westerly tilting of one degree an effective residue of four degrees to the east would survive, which, in the midst of a general dip of one degree or less, such as is the rule in Kansas, Oklahoma and Texas, would be very impressive. One realizes the caution with which sandstones are to be used in identifying structure, and the advantages which contacts with overlying shales present as against the internal stratification of the sandstones themselves.

Cusps.—While the sloping part of the beach may be said to have an inclination of 5 degrees, we must realize that it is seldom smooth, but for the greater part of the time is covered with ridges called cusps which run at right angles with the water's edge, and which are separated by much broader intervening hollows. The cusps begin just above the line where the surf breaks. Their fronts have a slope of about 10 degrees, so that they soon attain a height of two to four feet above the intervening hollows, whose bottoms maintain the normal slope of 5 degrees. The tops of the cusps are flatter than the bottoms of the hollows; and at the upper limit reached by the surf at high tide they fuse in with the general slope of the beach. Repeated pacing measurements from crest to crest gave a distance of 90 to 95 feet. From half-way down the slope of one to half-way up the slope of the next, is much farther than across the cusp itself. In profile therefore they simulate water-ripple-marks on a large scale as contrasted with wind-ripples.

Cusps are difficult to photograph because they present so little contrast of light and shade in the glaring white sand. In the series of pictures, Plates VI.–VIII. inclusive, an endeavor is made

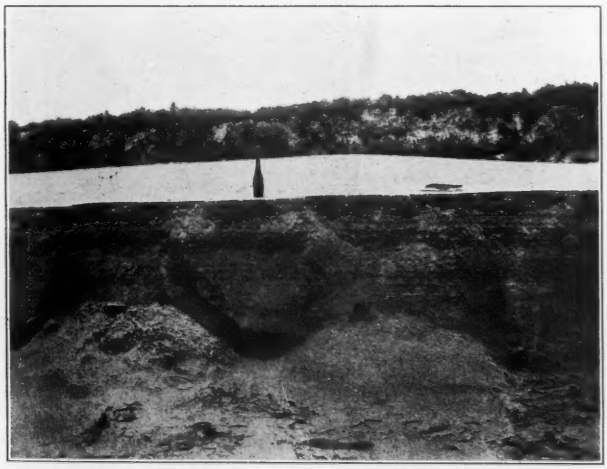
to illustrate their formation. Plates VI. and VII. *a* inclusive were all taken from the same point of view on different days and at varying conditions of tide and surf. Plate VI. *a* presents a flat beach, at low tide with gentle surf. All traces of cusps have been effaced. Plate VI. *b* shows the beginnings of cusps with a heavy surf, coming straight in shore, and with the tide nearly at flood. Plate VII. *a* illustrates the resulting cusps, but after a northerly gale with a slanting surf had cut off their seaward ends. While the surf had greatly quieted, the breakers are still rolling in "en échelon." Plate VII. *b* is the picture of the escarpment cut well back on the beach by the waves which in the night beheaded the cusps as shown in Plate VIII. Plate VII. *b* proves that the beach sands are visibly stratified. The conditions which produced Plates VII. *b* and VIII. are very unusual and the opportunity to photograph them would only appear at intervals of years.

The cusps proved to be a hard feature to explain, but by watching the conditions of the wind it became evident that they were formed by the surf when the wind blew straight in-shore, *i. e.*, from the east. Under these conditions, from some rhythmical spacing of the swash, the ridges and hollows result. When the wind is along-shore (and in Florida the severer gales are "northers" and in the winter come about once in three weeks) a strong shore drift is produced, giving a current in extreme cases of three miles or more an hour. The surf dashes on at a slant, and unless the waves are very violent, the fronts of the cusps become turned into hooks in the direction of the wind. They may even be beheaded altogether as shown above. Old cusps may thus present a variety of shapes. When the wind was from the west or off-shore, and this happened repeatedly in the months of April and May, the surf would be flattened out entirely. Along the beach the ocean was as quiet as any small pond, and a canoe could have been launched with perfect ease. Under such conditions no appreciable shore sculpturing could take place.

In at least one known instance cusps have been preserved in ancient sands now hardened to rock. The writer has been re-

a

FIG. *a*. Cusps, somewhat beheaded by slanting surf which has quieted. The tide is at flood and there is no surf on the outer bar. Viewpoint identical with Plate VI.



b

FIG. *b*. Stratified nature of beach-sands as exposed in a section cut by heavy, diagonal surf, during an unusually severe gale. Plate VIII. is on the same line of section, farther along the beach.

PLATE 4. Cusps beheaded by a diagonal surf, during an unusually severe, northern gale. The illustration, based on a photograph by the writer is taken from a forthcoming work on "Shore-lines" by D. W. Johnson and is loaned by the publishers, John Wiley and Sons.

minded through discussions of the subject with his colleague, Professor D. W. Johnson, of the ridges in the Medina sandstone near Rochester, New York, observed by the late G. K. Gilbert and brought before the Geological Society of America in 1899.[3] Mr. Gilbert was inclined to consider them ripple marks, but when he calculated the heights of the waves as the well-known function of the distance between summits of the ripples, heights were obtained which were almost unbelievable in amount. The writer was present at the reading of the paper and recalls the discussion. No one present could suggest any better explanation than gigantic ripple-marks, but we now realize that the phenomena were undoubtedly due to cusps. To the oil geologist it will at once be apparent that fossilized cusps, when later exposed, could give apparent dips of ten degrees, and if visible on only one side they might even afford apparent reversals of a very important character.

Coquina Limestone.—The cusps lead to the production of another feature of no small importance. At times the ocean casts on the beach large quantities of shells. The amounts for some reason vary with the season. During the winter of 1915–16 they were very abundant and a notable variety of species could be collected. During 1916–17 they were far fewer and rarely could any specimens of interest be found.

The following species were gathered, brought home and identified with the aid of Dr. J. J. Galloway and Dr. C. J. Maury, to whom acknowledgments are due.

LAMELLIBRANCHIATA.

Arca americana Gray.
Arca incongrusa Say.
Arca ponderosa Say.
Arca transversa Say.
Cardium magnum Born.
Donax variabilis Say.
Dosina concentrica Linn.
Lævicardium serratum Linn.
Mactra similis Say.
Ostrea virginica Gmelin.
Pecten nodosus Linn.
Pecten perpuratus Lam.
Pholas costata Linn.
Pinna rigida Dill.
Raeta canaliculata Say.
Tellina alternata.
Venus mercenaria Linn.

[3] G. K. Gilbert, Ripple-marks and Cross-bedding. Bulletin Geol. Soc. America, 10: 135, 1800. The cusps are called "giant ripples."

PLATE 4. Cusps beheaded by a diagonal surf, during an unusually severe, northern gale. The illustration, based on a photograph by the writer is taken from a forthcoming work on "Shore-lines" by D. W. Johnson and is loaned by the publishers, John Wiley and Sons.

GASTROPODA.

Cantharus variegatum Gray.
Cassis sulcosa Born.
Crepidula fornicata Lam.
Ianthina communis.
Neverita duplicata Say.
Oliva litterata Lam.
Sycotypus pyrum Lam.

CEPHALOPODA.

Argonauta argo Linn.
Spirula peronii Lam.

ECHINODERMATA.

Mellita sexforis Lam.

From the shell mound the following were brought home and identified. The most abundant of all is *Venus cancellata* Linn. Much less commonly—*Venus mercenaria, Ostrea virginica* Gmel., *Cardium muricatum* Linn. and *Arca americana* Gray. A large whelk was also noted and believed to the *Sycotypus pyrum* Lam., but no specimen was collected for identification.

When the cusps have been developed and are followed by a strong wind from either the north or the south, the surf dashes on the shore at an angle and drives all the available loose shells into the embayments provided by the hollows between the cusps. Under favorable conditions lenticular masses of shells will be brought together as much as a foot in depth. Almost all are water-worn and many are broken to fragments. If now changing conditions lead to their burial, the raw materials for lenses of limestone 30–60 feet long, and 20–40 feet across are provided. Descending rain-waters, and percolating sea-water operate to cement the loose components into a coherent mass and to produce a common kind of coquina. In fact, at any point along the beach when the surf removes the sand small ledges of coquina are liable to appear. Sometimes they jut out from the bench where the surf breaks, as will be later described; sometimes they form the bottom of the channel just beyond, so that a bather may walk on rounded rock bottom instead of sand; and sometimes they appear at low tide as positive small reefs running out from the shore. On account of the danger to fishing tackle occasioned by these reefs, the writer became extremely familiar with them and had some two miles of shore marked by stakes above the highest

surf and indicating limestone ledges, which could be detected at low tide or which had been revealed by entangling the sinker.

In the passage of the sands to rock, these slabs and lenses of shells and shell fragments would present small local developments of limestone, abruptly appearing in relatively coarse, mechanical sediments, an association not suggested by the ordinary conditions of deposition. We often consider limestones as relatively deep-water deposits, and sandstones as due to shallow-water conditions, whereas the coquina with shells often in sufficiently good condition to yield well-preserved fossils, accumulates just above the line of the breaking surf. It may also contain among its fossils not only shells from moderate depths of water, but deep sea organisms such as *Ianthina* and even the nautilus, *Argonauta*. As will be later shown in speaking of the puzzling things in faunal studies which may easily arise, we may have terrestrial shells intermingled and the hard fruits of terrestrial plants, washed up by the waves and brought from hundreds of miles to the south.

The Bench and Channel.—As stated above, the surface of the beach slopes upward at an angle of about five degrees. Along a line somewhat below low-water mark, the surface drops abruptly a vertical distance of two to three feet, forming a bench with a slope of thirty or thirty-five degrees. It then constitutes the bottom of the resulting "channel" and is practically level except for holes, ridges and hollows produced by the swirling and greatly agitated waters. The channel bottom continues 50 to 200 yards sea-ward and then rises again in the off-shore bar.

At the top of the bench and down its slope, the sand is largely replaced by coarse fragments of shells, extremely uncomfortable for the bare feet of a bather and thus brought emphatically to his attention. These coarse fragments stay right at the bench, or swash a little back and forth at its upper edge. The bench produces the in-shore surf. The waves after breaking on the off-shore bar, are reconstituted and roll across the channel until the bench retards their lower portion and makes them curl over as surf. The bottom of the channel, although in the large way

to be described as flat, is nevertheless ridged by coarse ripple marks parallel with the bench, by flow and plunge structures, and is excavated into holes sometimes a foot to two or three feet below the general bottom and one to several yards across. They are apparently due to small whirlpools and vortex motion in the water. Unwary bathers may easily step into depressions over their heads, and feeble or non-swimmers may find dangerous difficulties with the whirling suction, which is strongest at times of shore currents.

These inequalities may be, in part at least, produced at times of mild surf. Thus one could often observe at low or half tide under these conditions, that a local swirling movement would produce very roily water, as a wave rolled in and broke. The sand would boil upward, be dissipated, and settle out. In fact, one of the unexpected contradictions of the beach lies in the fact that at times of relatively gentle surf the sea-water is roily and useless for bathing, whereas with fairly or very violent surf and much greater agitation the water is beautifully clear. With an off-shore wind and gentle agitation and lapping of the waves, apparently the sediment is picked up and held in suspension most of all, often giving the normally green water a brownish cast. Under these conditions fishing was wasted effort.

All these inequalities of the bottom might easily be preserved and similar phenomena in ancient sea-beaches may explain some of the irregularities now discernible in sandstones and often quite puzzling. The channel is a favorite feeding ground of certain fish and for them the anglers cast their bait. The most prized fish is the so-called channel bass or red drum, *Sclaenops ocellatus,* ranging from 6 to 40 lbs. Sand-sharks, *Carchonias littoralis,* and others, up to seven feet in length, were often caught. Stingarees, *Dasyatis* Say, gave much annoyance. Being large and heavy when hooked they hugged the bottom and for hours could hardly be moved. Bluefish, *Pomatomus saltatrix,* two to three pounds, were almost always in evidence and so-called whiting, *Menticirrhus litoralis,* were especially abundant when the surf was not violent. The writer also landed one *Re-*

mora brachyptera, and several small sharks of different species from the one mentioned above. Catfish were in the channel and at times a great annoyance. Small fish mutilated by the blue-fish were sometimes cast ashore. Once for three successive days one could observe in the waves as they curled to break, a continuous procession of small fish about six inches long and almost filling the water. We thought them menhaden. Again when a school of blue-fish swept up the coast one morning under conditions of mild surf, the small fish fled up the beach in terror and were stranded so that one could gather them by the pailful. Thus to a degree which one would not ordinarily suspect the "channel" just beyond the inshore surf is populated by the finny tribe.

The Off-shore Bar.—The bottom of the channel rises at a slope of about ten degrees to form the off-shore bar. The top of the bar is flat and a few yards wide under normal conditions. It does not quite project at low tide, but is covered by water two or three inches deep. On the seaward side it slopes gently down, more gently than on the landward side. The captain of a small, disabled coasting steamship which ran in and anchored about a mile off-shore, told us that he was anchored in twenty feet of water. The depth would imply an off-shore slope of the bottom of less than half a degree. Off this part of Florida the sea-bottom must in this stretch go down very gently to deep-water. The off-shore bar maintains its position, as described, for the greater part of the time, but it is not permanent. The first winter of our stay, about a mile south of the cottage it had migrated inshore and joined the beach, so that the channel ended in a pocket, south of which the junction of the bar and beach formed a flat that projected seaward 20 yards or more. Opposite the cottage toward spring the bar at the time of a strong inshore gale started a slow shoreward migration and gradually pinched out the channel until it was reduced to a width of only a few yards and was finally cut off altogether. The bar became a hard, sandy, flat, running out for a score or more yards. The channel of a hundred yards across where we had caught many large fish became entirely obliterated, but for only about a hundred yards

along the beach. In this condition we left it in May, but the next November on our return, the old relations were restored and the off-shore bar was in its usual place one to two hundred yards from the beach and maintained this position for miles in either direction.

On the Mingling of Marine and Terrestrial Remains of Organisms.

As often indicated above, the writer's mind was constantly running parallels between the observed facts of the beach and the similar things to be seen and interpreted in the ancient strata. The accumulating sands and calcareous matter constantly suggested the old Calciferous Sand-rock of the early New York geologists, the transitional stratum from the Potsdam sandstone, to the Ordovician limestones, east and southeast of the Adirondacks, and now generally called the Beekmantown. From the facts above recorded one can readily understand how a limestone might be filled with grains of quartz, and might shade into the pure sandstones from which all calcareous matter had been leached by the rainwater. In some detailed structural work the past winter near Byrd's Store, north of Brownwood, Texas, the writer had to use as a key stratum, a bed in the Home Creek horizon, Canyon Series of Drake,[4] which was in some places a white quartz sand, in others a brown, tender sandstone, evidently weathered from limestone; and elsewhere a good limestone. It seemed almost incredible that one thin stratum could be so changeable in character. Exposures can be found, however, in the butte a half mile east of Byrd's Store, which show in one solid and unbroken bed, two feet of sandstone below, with four inches of limestone on top. When the limestone is well preserved and exposed the geologist would properly believe he was working on a limestone, yet if a few inches of the same identical bed were weathered off, he would find only sandstone and in separated exposures would be justly troubled about the identity of his key stratum.

[4] N. F. Drake, Report on the Colorado Coal Field of Texas, Fourth Annual Report, Geol. Surv. of Texas, I, 398, 1892.

The facts of the beach bring out also the possibilities of an extremely puzzling commingling of land and marine organic remains. At the top of the bank, fronting the sea, a flat coiled snail, *Helix* (*Polygyra*) *cereolus* Muhlf., is found at times in quite large numbers. There is also a gastropod, 1–1½ inches, with elongated spiral, *Euglandina rosea* Feruss., also var. *parallela* Binney, which are not so frequent. The shells of the former have rolled down the bank as a matter of observation; and there is no reason why the latter should not do the same. They thus become mixed with shells thrown up by the surf in times of storm and might all be buried and in the end fossilized. One frequently sees on the beach very resistant fruits of four different plants. One is derived as a bean from a long vine, *Canavalia lineata* (Thunb.) D. C., which grows on and at the foot of the bank fronting the beach. The bean is extremely hard, brown and about a half inch long. If not too well preserved as a fossil there are several palæozoic molluscs and crustaceans (*Leperditia*, for example) which it would strongly resemble. The other three beans are washed ashore from habitats hundreds of miles to the south. One, the fruit of *Mucuna altissima* Jacq., is a flattened spheroid, an inch or less in diameter, with a black band encircling the junction of the cotyledons. The bean is washed to Florida from Cuba, or other islands of the West Indies. It is often used as a watch charm. Fossilized it would in the first place be far from its point of growth and in the second place might easily be mistaken for a smooth, rounded globose brachiopod of poorly preserved hinge line. The third one is a huge bean, flattened, cordate in shape, 2–2½ inches in diameter and a half inch thick, the fruit of *Entada scandens* (L.) Benth., a mimosa native in Cuba.[5] It would yield a fossil extraordinarily like a poorly preserved sea-urchin such as *Enallaster texanus* Roem., which one sees in the Texas Comanchic. The last fruit as determined by Dr. O. F. Cook, of the Department of Agri-

[5] From Dr. N. L. Britton of the New York Botanical Garden the writer learns that this bean is washed ashore as far north as New Jersey, and has even reached Norway.

culture, is the nut of the palm, *Manicaria saccifera,* a native of the Orinoco region. It is spherical and up to 1½ inches in diameter. A shelly rind encloses a central part, hard and resistant. It would yield a round mould, about whose reference to the animal or vegetable kingdom a future palæontologist might well hesitate. All these are being buried with a vast predominance of marine shallow water and deep water forms, of such well-known genera as to cast doubt on the nature of their obscure association. The past has doubtless furnished us with similar puzzles and traps for the palæontologist.

The Indian River.—In the Indian River, a half mile from the Atlantic surf, with its coarse sediments, conditions are entirely different. Organic life is abundant. The water is quite stagnant except for the movement produced by the winds. Along the shore the odor of decaying organisms, cast up by the small waves, is very apparent. Where the chocolate-colored waters of creeks draining the mainland flow in from swamps and bogs, abundant, finely macerated vegetable matter and some fine mud are added to the bottom. Bituminous shales would undoubtedly result from these flat deltas. Were subsidence of a few feet to take place, the sea would spread a layer of coarse sand over all these richly bituminous shales, and an excellent series for oil formation would be afforded, and would lie between the sands of the present bottom and the sands which would be spread over the delta deposits by the incoming ocean. Below all would lie the 200 feet more or less of shale, already proved by the artesian borings. The conditions are strongly reminiscent of many successions of strata which one sees in the Mid-Continent Field.

Along both shores of the Indian River coquina limestone is sometimes continuous as ledges for stretches of a mile or more. It has resulted from the accumulation of shells or other calcareous remains as beds not connected with surf and cusps. It would yield in connection with subsidence, quite extended lenticles of limestone, up to at least six feet in thickness. In many places along the rocky bench, and especially at Eau Gallie, the coquina is penetrated by circular holes, a foot or so in diameter

and up to four feet deep. The writer endeavored to account for these by the dissolving action of descending waters at the intersection of joints, but could find no joints of uniform distribution and was finally driven to the local explanation that they are produced by the roots of palmetto trees which must in some way in their downward growth lead to the solution and removal of the limestone. If future subsidence enables the ocean to deposit its sands over these lenticles of limestone, tubular bodies of sandstone will result, thickly set in richly fossiliferous limestone, and in no respect due to pot-holes or any such cause as would naturally suggest itself.

NATIVE COPPER AND SILVER IN THE NONESUCH FORMATION, MICHIGAN.

KEIJIRO NISHIO.

GENERAL DESCRIPTION.

The Keweenaw Point, or Copper Range district is famous for the great native copper and silver deposits. The Point projects northeastward into the Lake Superior from its southern shore.

The principal rocks in the district belong to the Keweenawan series, Algonkian system, which is divided into (1) lower, (2) middle and (3) upper Keweenawan series.[1] The lower Keweenawan consists of conglomerates, sandstones, dolomitic sandstones, shales and marls; the middle Keweenawan comprises basalt flows with interstratified sandstones, conglomerates and shales; and the upper Keweenawan comprises also conglomerates, sandstones and shales. In this district they strike northeast and dip northwest towards Lake Superior.

The deposits of native copper and silver are found in the middle and the lower part of the upper Keweenawan series.

The Nonesuch formation belongs to the upper Keweenawan series and ranges from a soft, fine-grained, highly argilaceous shale to a sandstone. The shale is predominant, the sandstones are found interbedded with the shale. They are composed of detritus from the porphyries and other acidic rocks of the Keweenawan, mingled with more or less basic detritus.[2]

The occurrence of the native copper and silver in this region may be classified as follows:

(1) The deposits in the amygdules of the basalt flows with other minerals. (2) The deposits in conglomerates of the middle part of the series. (3) The deposits occurring in the form

[1] Van Hise, C. R., and Leith, C. K., "The Geology of the Lake Superior Region," U. S. Geol. Surv. Mon., Vol. 52, 1911, pp. 366–367.

[2] *Idem*, p. 383.

of transverse or dipping veins. (4) The deposits in the Nonesuch formation of the upper Keweenawan occurring with carbonaceous matter in the sandstones.

The deposits of the first and second class form the important resources of copper in this region.

There are several hypotheses concerning the origin of the native metals. Pumpelly[3] sought the source of the copper in the sedimentary rocks; Wadsworth,[4] Irving,[5] and Lane[6] in the basalt flows; while Smyth[7] and Van Hise and Leith[8] believed that the concentration was effected by thermal solution.

THE NATIVE COPPER AND SILVER IN THE NONESUCH FORMATION.

At the Nonesuch mine occurs a bed of sandstone 4 feet thick, containing copper in workable amount, beneath it a few feet of shale also with some copper, and again underneath some two and a half feet of light gray sandstone, well known for its silver content. The Nonesuch formation has no covering basalt and it is also separated downward by the Outer conglomerate, 3000 feet thick, from Lake Shore trap (basalt), 400 to 1800 feet thick[9] (Fig. 21). The occurrence does not seem explainable by any one of the previous hypotheses. Hence Irving considered it as "an important exception."

Irving recorded the occurrence of minute cores of magnetite in native copper in the Nonesuch sandstone.[10] Van Hise[11] tried

[3] Pumpelly, R., "Copper District," Geol. Surv. of Michigan, Vol. L., Part 2, 1869–1873, p. 42.

[4] Wadsworth, M. S., "Notes on the Geology of the Iron and Copper District of Lake Superior," 1880, p. 130, and "The Origin and Mode of Occurrence of the Lake Superior Copper-Deposits," *Trans. Am. Inst. Min. Eng.*, Vol. 27, 1898, pp. 692–695.

[5] Irving, R. D., "Copper-Bearing Rocks of Lake Superior," U. S. Geol. Surv. Mon., Vol. 5, 1884, pp. 419 and 426.

[6] Lane, A. C., "The Keweenaw Series of Michigan," 1911, pp. 42–44.

[7] Smyth, H. L., "On the Origin of the Copper Deposits of Keweenaw Point," *Science*, New Series, Vol. 3, 1896, p. 251.

[8] U. S. Geol. Surv. Mon., Vol. 52, pp. 588–590.

[9] U. S. Geol. Surv. Mon., Vol. 5, p. 420.

[10] *Idem*, p. 132.

[11] Van Hise, C. R., "A Treatise on Metamorphism," U. S. Geol. Surv. Mon., Vol. 47, 1904, p. 1103.

to explain the occurrence by the reducing action on copper salt by the magnetite, but lately suggested that the native copper and the magnetite were both precipitated as a result of the reaction of ferrous salts with copper salts according to Stokes' experiment,[12] and was obliged to suppose two stages of precipitation

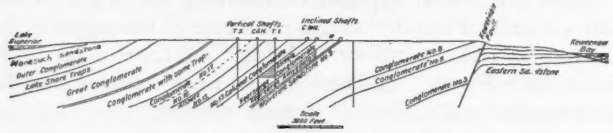


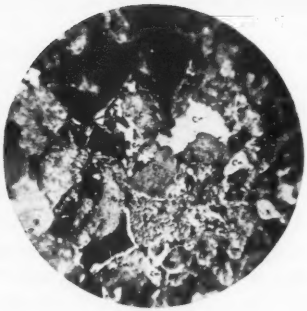
FIG. 21. Cross-section of the copper range near Calumet. After Lane.

for them; that is to say, a hotter stage for the precipitation of magnetite and colder for that of the native copper, but he did not explain the process of the alteration of ferric oxide into magnetite.

Mr. E. S. Gierson[13] was kind enough to furnish me with several specimens of sandstone ore of the Nonesuch formation from White Pine mine at the time of my visit. The sandstone is gray in color, and has marked oily odor. Under the microscope the sandstone is seen to be composed of fragments of porphyry and quartz. The interspaces between the fragments are lined with chloritic substance. With reflected light it is seen that the interstices between the fragments are in places filled with pitch- or coal-black substance, which occurs side by side with native copper, sometimes surrounded by or pierced through by the copper (Plate IX., *a*), and the copper sometimes replaces some of the fragments (Plate IX., *b*). In a section from another specimen, chalcocite occurs with black coaly substance in such a mode as above described for the native copper (Plate IX., *c*). The black substance is identical in mode of occurrence with the magnetite described by Irving and Van Hise. I could never find magnetite in the specimens. When the sandstone was crushed into a fine powder, and tested with an electromagnet, nothing was attracted. The black

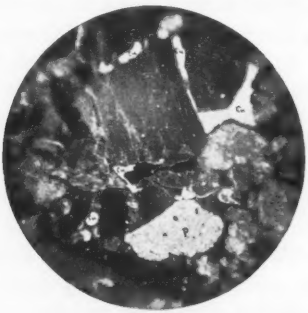
[12] Stokes, H. N., "Experiments on the Solution, Transportation and Deposition of Copper, Silver and Gold," ECON. GEOL., Vol. 1, 1906, pp. 644–649.

[13] General superintendent of the Calmet and Hecla Mining Company.



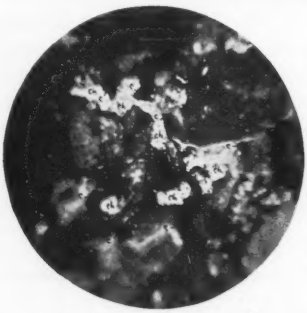
a

C, Carbonaceous matter; *Cu*, native copper, magnified 54 diameters.



b

C, Carbonaceous matter; *Cu*, native copper; *P*, native copper replacing the ingredients of fragments. Magnified 54 diameters.



c

C, Carbonaceous matter; *Ch*, chalcocite. Magnified 36 diameters.

substance floats on water, and is infusible in the closed tube before the blowpipe. It remains dry and powdery, and moves freely on the glass surface; it is also insoluble in hydrochloric acid and floats on its surface like coal. Heating in the closed glass tube with manganese dioxide, it glows (burns) and leaves a residue of white to reddish material (quartz). The black substance is very soft (H.$=2\pm$), brittle, and exhibits concoidal fracture. Thus it is proved to be carbon, and not magnetite.

Mr. D. Saito[14] kindly analyzed for me the black substance by the following methods:

1. The sample was first put in a desiccator with concentrated sulphuric acid for ten days to take off the last trace of moisture.

2. *Determination of Volatile Matter.*—0.05 gram of sample was placed in a porcelain boat and pushed into a hard glass tube in a combustion furnace. The atmosphere in the tube was at first replaced by nitrogen to hinder the oxidation during heating. Le Chatelier's pyrometer was inserted into it to measure the heating temperature. Then the sample was heated at 300° C. for 30 minutes to drive out the volatile matter. Then the sample was cooled down in a nitrogen current, and weighed. The decrease of the weight gives the amount of volatile matter.

3. *Determination of Carbon (Fixed).*—The above treated sample was similarly put into a hard glass tube as above described, and was heated at red heat in a weak current of oxygen. Thus carbon dioxide gas evolved from the complete combustion of carbon was totally absorbed into the solution of caustic potash. From the increase of the weight of the caustic potash tube, its carbon content could be calculated.

4. *Determination of Ash.*—The weight of the residue from the above described test gives the amount of its ash-content by simple calculation.

The analytical results of the black substance are:

	Per Cent.
Volatile matter	2.4
Carbon (fixed carbon)	64.8
Ash	33.3
	100.5

[14] Professor of iron metallurgy in the Kyoto Imperial University.

The ash has a brownish color which is chiefly due to iron. Its chief constituent seems to be iron oxide and silica; alkalies are not present. As the amount of the sample was too small, no analysis of it could be made.

I know by another analysis that the volatile matter contains 5.35 per cent. of hydrogen, and the ash contains 2.34 per cent. of copper.

The black substance, associated with the native copper and the chalcocite in the Nonesuch formation, is thus amorphous carbon, containing some hydrocarbons, which would probably have an intimate relation to the genesis of the native copper and the chalcocite. I have no specimen of native silver ore from the Nonesuch formation, hence I do not know whether the native silver accompanies some carbonaceous matter, or not, but the native silver may probably occur associated with carbonaceous matter as the native copper does.

Knopf[15] studied the copper-bearing amygdaloids of the White River region, Alaska, and stated that the vesicules of the amygdaloid are filled with a black coaly mineral and in places contain considerable metallic copper. He suggested that the ascending thermal solution might have caught up woody material from some tuff beds underlying the cupriferous amygdaloids, and he ascribed the precipitation of metallic copper to the reaction of the carbonaceous matter with the thermal solution. He also found chalcocite with native copper. Finally he added that "no explanation had been advanced yet as to why in some cases carbonaceous matter precipitates metallic copper and in other chalcocite."

Though the coaly substance might sometimes be transported in solid state into the vacuoles from some under-lying beds, the carbon would not react upon the thermal solution, unless the former was heated to red heat. Therefore Knopf's hypothesis would be imperfect to explain the genesis of the metallic copper, silver and carbonaceous matter in the amygdaloids.

[15] Knopf, Adolph, "The Copper-Bearing Amygdaloids of the White River Region, Alaska," ECON. GEOL., Vol. 5, 1910, pp. 252–256.

GENESIS OF THE NATIVE COPPER, SILVER AND CARBONACEOUS MATTER IN THE NONESUCH FORMATION.

The carbon being amorphous and containing the gases of some hydrocarbons, it seems natural to explain the genesis as a simultaneous precipitation of metals and carbonaceous matter, when the solution of the metals was acted upon by the gases of certain hydrocarbons.

Hatschek and Simon[16] have obtained colloidal gold and carbon from silicic acid gel, containing a small quantity of gold chloride, by the reducing action of illuminating gas. By this they explained the occurrence of gold with graphite and also of silver or cassiterite with graphite. This result may be applicable to the occurrence of native copper or silver with carbonaceous matter. Rassenfosse[17] got colloidal copper from cupric sulphate in concentrated sulphuric acid by such reducing agents as ethyl- and methyl-alcohol, ether, aceton and oxalic acid. According to Castoro[18] colloids of gold and of metals of the platinum group were obtainable by reduction with various hydrocarbon and similarly other colloidal metals from the very dilute solution of copper, silver, bismuth, mercuric mercury and so forth, especially by the reducing action of formaldehyde, hydrazin hydrate and phenol. Therefore it may be expected to find colloidal copper and silver produced from their solution in percolating waters or thermal solution by a reducing agent such as organic matter, from which carbon may also be produced at the same time.

A. *Experiments to Precipitate Metallic Copper and Carbonaceous Matter*—After several experiments there was obtained metallic copper and carbonaceous matter, intermixed with the copper acetylide, from a solution of copper sulphate by

[16] Hatschek, E., und Simon, A. L., "Die Reduktion von Gold in Kieselsäuregelen und die Entstehung von Goldlagern," *Zeitsch. für Chemie und Industrie der Kolloide*, Band 10, 1912, S. 265–267.

[17] Rassenfosse, A., "Ueber eine neue Bildung von Kolloidem Kupfer," *Chemisches Zentralblatt*, 1911, I. S. 122.

[18] Castoro, N., "Ueber die Darstellung Kolloider Metalle mit Hilfe von Akrolein," *Zeitsch. für Chemie und Industrie der Kolloide*, Band 6, 1910, S. 283.

passing acetylene gas, purified by passing through the solution of copper sulphate, acidulated with sulphuric acid. This reaction may be effected in the saturated solution of copper sulphate at boiling temperature, as well as in the dilute solution in cold state, until all of the copper is extracted from the solution. The reaction is facilitated by addition of ferrous sulphate solution, or by using the acetylene gas mixed with carbonic acid gas. The copper acetylide, prepared from the ammoniacal solution of cuprous chloride, by passing through acetylene gas, is always impure, containing some metallic copper and black carbonaceous matter. The darkness of its color is due to the impurities. If the copper acetylide is kept wet and exposed to daylight, its color will become darker by the separation of a black substance, until no difference is seen between it and the copper acetylide from the copper sulphate.

Copper acetylide dissolves in dilute hydrochloric acid leaving behind black residue. On neutralizing the filtrate with ammonia, a red precipitate of copper acetylide appears again, which may be considered practically pure. It will also change to the darker color, gradually separating carbonaceous substance and metallic copper.

The copper acetylide dissolves readily in hydrochloric acid, sulphuric acid and hydrogen iodide, but slightly in acetic acid and ammonia.

The black residue is chiefly composed of carbonaceous matter mixed with metallic copper. Attempts were made to separate the black substance and metallic copper from the copper acetylide, and to examine them by the following methods:

To dissolve the copper acetylide leaving metallic copper in carbonaceous matter there was used hydrogen iodide (normal solution), concentrated acetic acid, and dilute sulphuric acid; to detect metallic copper in the black residue, mercuric chloride, mercury and concentrated nitric acid; and to prove carbon, potassium dichromate and concentrated sulphuric acid, cupric oxide and concentrated nitric acid, and aqua regia.

.1. Shake a little of the darker copper acetylide from copper

sulphate, or copper acetylide, preserve for several days, with a normal solution of the hydrogen iodide[19] in cold state. As the hydrogen iodide readily dissolves the copper acetylide and metallic copper, the treatment is quickly accomplished, and the black residue is washed with potassium iodide, until no copper iodide is left, and again with water.

To prove the presence of metallic copper in the black residue:

(*a*) Shake the black residue with mercuric chloride in the cold state. If metallic copper is present, copper chloride will be formed in it and the filtrate will change to blue by the neutralization with ammonia.

(*b*) The black residue is ground with mercury in a mortar. The globule is washed well and then boiled with concentrated nitric acid. If copper is present, the filtrate will change to blue by neutralization with ammonia.

(*c*) The black residue is boiled with concentrated nitric acid. If copper is present in it, the filtrate will change to blue by the neutralization with ammonia.

To prove carbon in the black residue:

(*a*) Boil the black residue in concentrated sulphuric acid and potassium dichromate, or heat the dried black residue mixing with powdered cupric oxide in a closed tube. The evolving gas is introduced into lime water to see if the white precipitate caused by carbon dioxide may be seen, denoting carbon in the black residue.

(*b*) The black residue is boiled at first with concentrated nitric acid and lastly in aqua regia. If the black residue contains carbon, in the both cases there will be change.

2. Shake the darker copper acetylide from copper sulphate, or copper acetylide, preserve for several days, with cold dilute sulphuric acid to decompose the copper acetylide, until the black residue no longer explodes. The black residue is treated as above described to prove the presence of metallic copper and carbonaceous matter.

3. Boil the darker copper acetylide from copper sulphate, or

[19] Hydrogen iodide is prepared by the method of phosphorus and iodine.

copper acetylide, preserve for several days, with concentrated acetic acid, until the black residue no longer explodes, and the filtrate shows no copper. Then the black residue is treated as above described, to prove the presence of the metallic copper and carbonaceous matter.

For further study I placed in a desiccator the sample of the carbonaceous matter taken from the darker copper acetylide from copper sulphate, until it had constant weight. The sample was then put in a closed tube, the air in the upper part of which was replaced by carbon dioxide gas. The tube was heated to 300° C. for thirty minutes in the metal bath, to drive out the volatile matter contained in the sample. Then it was cooled in the desiccator, and the decrease of its weight determined. The sample was ignited in a platinum crucible and examination of the ash showed it contained no iron, copper or silver. The percentage of carbon was obtained by subtracting the volatile matter and ash from one hundred. The results are as follows:

	Per Cent.
Volatile matter	26.02
Carbon	73.86
Ash	0.12
	100.00

By the methods above mentioned, the association of metallic copper and carbonaceous matter, which may be obtained by the reduction of acetylene gas upon the solution of copper sulphate, have been proved. The occurrence of the chalcocite in the sandstone may have been produced by the alteration of native copper, formed as above described, but the chalcocite may also have been produced with carbonaceous matter by the incomplete reduction of acetylene gas upon the solution of copper sulphate.

B. *Experiments for Metallic Silver and Carbonaceous Matter.* Attempts have been made to obtain metallic silver and carbonaceous matter from a solution of silver sulphate by passing acetylene gas through it, but there was always obtained metallic silver and some organic compounds of silver, but never carbonaceous matter. In the presence of considerable ferrous sul-

phate, the silver sulphate, dissolved in dilute sulphuric acid, produced metallic silver, some organic compounds of silver[20] and carbonaceous matter, by passing acetylene gas through it. The silver acetylide, obtained from the ammoniacal solution of silver nitrate by passing the acetylene gas, becomes darker by separation of metallic silver, some organic compounds of silver, and carbonaceous matter, on standing in the moisture and sunlight, as does the acetylide.

As potassium cyanide readily dissolves silver acetylide and the organic compounds of silver, it was used as the reagent to separate the metallic silver and carbonaceous matter. The presence of the metallic silver in the black residue is proved by amalgamation, or by the white precipitate of silver chloride, produced by addition of dilute hydrochloric acid into the filtrate, after boiling the black residue with concentrated nitric acid. The carbon in the black residue is proved by the methods as described in the case of metallic copper and carbonaceous matter.

Thus it has been proved that the black residue, free from silver acetylide and some organic compounds of silver, is composed of metallic silver and carbonaceous matter.

CONCLUSION.

Though Mendeleeff[21] has suggested the presence of metallic carbides in the interior of the earth to explain the genesis of petroleum, the actual existence of such carbides in nature has not yet been proved.

According to Berthelot, acetylene gas is naturally produced by the incomplete oxidation of organic compounds at ordinary temperature. The gas is also produced by the incomplete combustion of hydrocarbons and other organic bodies, or by passing a mixture of methane and carbon monoxide through a red-hot

[20] The organic compounds of silver dissolves in potassium cyanide, but not in concentrated sulphuric acid, it is decomposed by hydrogen iodide. *Berichte der Deut. Chem. Gesch.*, Vol. 10, 1877, p. 229.

[21] Mendeleeff's "Principles of Chemistry," Vol. L., pp. 396–401, and [22] Watt's "Dict. of Chemistry," pp. 41–42.

tube.[22] As the sedimentary rocks always enclose more or less organic substance, which undergo incomplete oxidation, it may naturally be deduced that the acetylene gas or like gases may be widely diffused in the sedimentary rocks, especially in the case of the Nonesuch formation where traces of crawling animals and sea weeds have been suggested.[23] Therefore, we may also expect the occurrence of native copper or silver with carbonaceous matter at places where the solutions of the metallic salts might come into contact with acetylene or similar gases. The deposits of native copper or silver associated with carbonaceous matter in the Nonesuch sandstone, and that of the native copper associated with coaly substance in the vesicules of the amygdaloid in the White River region, Alaska, may be explained by the reaction of acetylene gas or like gases upon the metallic solutions.

I hope to discuss at a later date the origin of the native metals, in the Nonesuch sandstone, and in the Keweenaw Point districts.

Formerly the formation of the native copper in gossan was chiefly ascribed to the reaction of dilute sulphuric acid upon cuprite. At the old mines of Rio Tinto and Chessy, the crystals of native copper were separated from the dilute solution of copper salts by the contact with rotten timbers for a long time.[24]

The native copper in both cases was originated by the reduction of copper solutions by the gases of hydrocarbons, generated by the decay of the timbers. It is possible that similar reactions may have played some part in the formation of the principal copper deposits of Lake Superior.

[23] Lane, A. C., The Keweenaw series of Michigan, p. 40.
[24] Hintze, Carl, "Handbuch der Mineralogie," I. Abt., S. 216.

NOTES ON THE PLACER MINES OF CARIBOO, BRITISH COLUMBIA.

J. B. Tyrrell.

In a brief trip made to the placer mines of the Cariboo district, British Columbia, in the summer of 1918, some data were gathered pertaining to the distribution and geological features of the auriferous gravels, particularly in regard to the existence of extensive beds of pre-glacial gravels below Glacial deposits, and the greater influence of stream piracy over glaciation in changing the courses of streams. They are here presented in the form of brief notes.

It is not my intention to describe the configuration of the country, the details of its geology, or the extent to which it is being mined. The Geological Survey of Canada began a survey of the area last summer, and intends to continue it until it is able to publish a complete report with detailed maps of the geology and structure of the country, not only of the older rocks which underlie it, but also of the later formations and of the influences to which it has been subjected to form its mountains and valleys, and to deposit the gold in the bottoms of these valleys.

Mr. Bowman, of the Geological Survey of Canada, made an examination of the country some years ago and published a number of good maps of the whole district, and of several of the gold-bearing creeks. With these he published a report on the older rocks underlying the country. Possibly the material pertaining to the gravels collected by Mr. Bowman may be incorporated in the report which is now to be published by the Geological Survey.

HISTORICAL DEVELOPMENT.

For many years the country was surrounded with a halo of glory and mystery. Discovered in the winter of 1860–61 by prospectors travelling overland through the rugged mountains to

the south, over which it was almost impossible to transport supplies, and on which the hardy frontiersmen were obliged to depend for food on the caribou that roamed through the forests, it was indeed a difficult country to reach, but after it was reached the rewards to the pioneers were great. Writing in the autumn of 1861 Governor Douglas says that he had met a large number of men who had returned from the new gold camp, and without exception they had all been successful, a statement which cannot be made for many camps.

After gold had been discovered at the Cañon on Williams Creek by William Dietz (Dutch Bill) word was quickly passed back to the prospectors scattered along the Fraser River and they soon made their way to the new Eldorado. In 1862 and 1863 many parties came in from the south and also across the plains and mountains from the east until a few years later Barkerville, the center of the new district, was second only to Victoria in population in what is now the Province of British Columbia.

Since 1858 up to the end of 1917 the Government Reports show that British Columbia produced about $75,000,000 worth of placer gold. Of this amount the Cariboo country, not including the Quesnel district, produced gold to the value of $41,500,000. I have not at hand the details of the various creeks, but probably of this total, Williams Creek may have produced about $25,000,000 and Lightning Creek $5,000,000. Mr. Muller informed me that Williams Creek above the Cañon produced about $1,000 to the running foot and below the Cañon, for a couple of miles, about $600 to the running foot. Most of this was produced from shallow ground, where the whole material from the surface downwards to the bottom of the paystreak was shovelled into sluice boxes, in which the lighter sand and gravel were carried away by the water, while the heavier gold was left in the riffles.

In the bottoms of some parts of the valleys the alluvial deposits were too deep to be handled in this way, and there shafts were sunk to bed rock, and drifts were run on or in bedrock

through which the rich gold-bearing layers was extracted and washed in sluice boxes.

Unlike the conditions in the mines of the Klondike the gravels here were not perennially frozen, and consequently water was usually present in great quantity. The unwatering of the deeper mines was therefore a serious and expensive problem and with greater increase in the depth of the overburden, water finally rendered the deep ground unworkable. I could not learn of any individual instance where miners were actually driven out of rich pay gravel which they were mining, by water, but exploration and development of deep ground have undoubtedly been stopped by water, even where rich prospects were obtained. The question therefore at once arises, how much valuable gold-bearing ground is there still in the district awaiting cheaper transportation, and larger and more energetic mining methods.

TOPOGRAPHY.

On the east is a high rugged range of mountains rising in jagged peaks to heights of about 7,000 feet. This range limits the known gold-bearing area in that direction. West of it are more detached mountain masses, rising in some peaks like Mount Agnes or Bald Mountain, to heights of 6,200 feet, while farther west the country declines in a series of high transverse ridges separated by deep valleys towards the main valley of the Fraser River. The tops of the higher mountains above the elevation of about 5,000 feet are open moorland on which the snow lies until well on in the summer, but below this level the slopes are thickly wooded with fine forests of spruce and balsam, many of the trees in which, in the vicinity of Stanley, would average 18 to 20 inches in diameter, while some are as much as 31 inches. Fortunately forest fires do not appear to have swept over these mountain sides to the same extent as they have swept over many of the forested areas in eastern Canada.

CONDITIONS AND DEVELOPMENT OF DRAINAGE.

The underlying rocks are mostly schists and slates which have been called by Bowman the Cariboo Schists, and the prospectors

from Ontario would be struck with the resemblance of these schists to the Keewatin Schists of the northern portion of their own Province, or miners from the Klondike might consider them the Klondike Schists which Mr. McConnell has so well described in "The Klondike Gold Fields." Many quartz veins have been found running through these schists holding gold in appreciable quantities, but as yet none have appeared to deserve serious development under the difficult conditions of transportation still prevailing in that country. These schists are doubtless of Pre-Cambrian or early Paleozoic age, and the mountains of

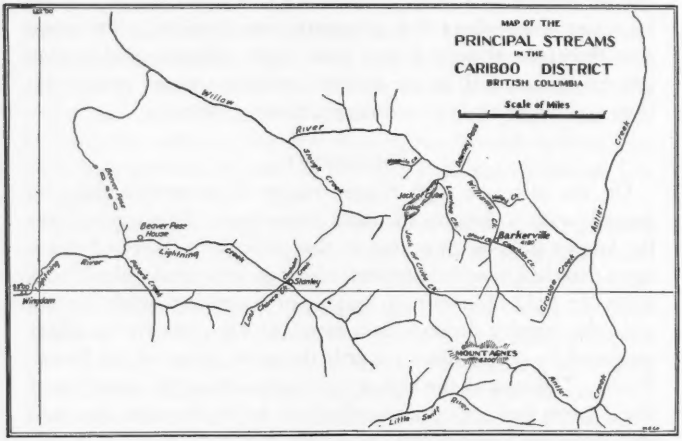


FIG. 22.

which they are composed may have been formed during several succeeding periods of uplift and disturbance, the last of which may possibly have occurred since Oligocene times. In this case an additional point of touch with the mountains of the Klondike would be indicated, as these latter include in their folds beds of Miocene or Oligocene age.

Subsequent to the final period of mountain building a long epoch of erosion set in, during which valleys were developed

radiating from the important mountain masses in all directions. Of these mountains, Mount Agnes or Bald Mountain, is the most conspicuous. From it Little Swift River flows to the south, Grouse and Antler Creeks to the east, Williams and Jack-of-Clubs Creeks to the north, and Lightning Creek to the west. It is impossible not to recognize the marked resemblance of this central point to the Dome at the head of Bonanza Creek in the Klondike. It is true that Mount Agnes is 2,000 feet higher above the sea than the Dome, but the bottoms of the surrounding valleys are also about 2,000 feet higher than the valleys that radiate from the Dome and as both sets of valleys are of about the same depth, with sloping wooded sides, the general similarity of the natural features of the two districts is quite striking.

Williams Creek.—While the valleys were being formed the streams did not always follow their present water courses. For instance, the valley of Conchlin Gulch which comes from the southeast, crosses Williams Creek, and is continued as Stout Gulch and Lowhee Creek until it opens into Slough Creek as a hanging valley. Between what is now Conchlin Gulch and Stout Gulch the present drainage is crossed and intersected by Williams Creek, the lower portion of which is therefore of later age, though the upper portion was probably originally a tributary of Conchlin Creek. Consequently the old wash of this old Conchlin-Stout-Lowhee Gulch is of a greater age than the gravel in the bottom of the lower part of Williams Creek, and the stream which once flowed in it was older than the latter creek. The drainage down Conchlin-Stout-Lowhee Creek must have persisted for a comparatively long time, as the old valley is wide and mature, though the present creeks have cut narrow gorges in the bottom of its floor.

The main valley of Williams Creek at that time extended up Valley Creek, and down Willow River. Then one of its tributaries from the south, which extended up past the present site of Barkerville, cut into the side of Conchlin-Stout-Lowhee Creek, and robbed it of its water, drawing the gold-bearing gravel with it down into that portion of Williams Creek below the Cañon.

From that time onwards Conchlin Creek discharged into this newer part of Williams Creek, and Stout Creek developed a gorge (Plate X., *a*) in the upper part of the abandoned Stout-Lowhee valley in which it flowed eastward into Williams Creek, instead of northwestward as before.

But stream piracy did not end in the robbing of the water of Conchlin-Stout-Lowhee Creek by Williams Creek. Slough Creek for some reason deepened its channel and formed a great wide valley (Plate X., *b*), the floor of which was about a third of a mile across. It must have cut back and robbed the water from the Williams-Willow river, for Jack-of-Clubs lake, which lies in its valley, is reported to be 200 feet deep, and the bedrock in its valley a little farther west was found by drilling to be 287 feet below the surface, while the lowest part of the bedrock in the valley of Willow River was only 102 feet below the surface, which was probably a little higher than the surface at the drill hole near Slough Creek. Thus the original bedrock bottom of the valley of Slough Creek is nearly 200 feet deeper than that of Willow River, and consequently it undoubtedly robbed the water from the latter stream.

In excavating its great valley the old Slough Creek, which had doubtless become a large and important river through the addition of Williams Creek, and probably also of Valley and Downie-Pass Creeks, cut away the lower portion of the almost abandoned valley of Lowhee Creek, and of the wide valley of Jack-of-Clubs Creek, reducing them to hanging valleys on the side of the master valley. The original courses of the lower parts of the streams that occupied these two old hanging valleys was not apparent, but it is possible that they turned westward and then southwestward in what is now the valley of Chisholm Creek, and thus flowed into Lightning Creek, for the upper portion of Chisholm Creek valley was also cut away by Slough Creek.

Lightning Creek.—Lightning Creek valley is narrow and V-shaped as far down as Stanley, the narrow channel in its rock floor being often not more than 20 or 30 feet in width. At Stan-

a

a. Mouth of Stout's Gulch from William Creek showing tailings from hydraulic operations in the foreground, and gorge in the bottom of the old mature valley in the back center.

b

b. Wide Valley of Slough Creek looking northwestward from Mosquito Cr.

c

c. Cliff of boulder clay from bedrock to surface on Stout's Gulch.

ley the wide U-shaped valley of Chisholm Creek joins it from the north, and thence downwards the whole valley is wider than before, and maintains a U-shaped character. At a place known as the Beaver Pass the main valley swings off to the north, and doubtless the drainage ran for a long time in that direction, but the present stream turns southwestward into a narrow gorge between rocky walls, and continues in it past Wingdam towards its junction with Swift River to form Cottonwood River. Close to Beaver Pass Peters Creek flows into Lightning River from the south, and whether the narrow valley of Lightning Creek below the confluence of these two streams was once the continuation of its valley, or was the valley of a tributary in which the drainage has been reversed, is uncertain, though the latter supposition is probably the correct one. I was not able to learn the depth of bedrock below the surface at Beaver Pass, but it is probably several hundred feet, for according to information received from Mr. M. Bailey, the depth from the surface to bedrock about four miles farther up Lightning Creek is 205 feet, and while the grade of the surface between the two places is very light, the grade of the bedrock is probably much steeper.

This will indicate the conditions of drainage, and the characters of the valleys that had been formed by it at the end of the Pliocene Period, and it will be seen that in pre-Glacial times wide mature valleys had been formed, but stream piracy had been taking place and the streams that formed these valleys were robbed by other streams that flowed in deeper valleys.

Accumulation of Gold.—During this time gold was being concentrated into the bottoms of some of these valleys in larger or smaller quantities, according to the abundance of the supply, the excellence of the bedrock for forming riffles, or the length of time through which the concentration was operative. If similar conditions had continued down to the present there would have been several wide valleys in the district with beds of gravel covering their bottom lands, through which paystreaks would run. Deep narrow V-shaped valleys and gulches would discharge into them, sometimes from hanging valleys, while in embayments

along their sides would probably occur gravel-covered erosion terraces.

The continuity of conditions of erosion was suddenly broken by the advent of the Glacial Period. There was no general Cordilleran glacier in this district with a motion southeastward or northwestward parallel to the trend of the mountains, but the country was heavily glaciated by local glaciers that flowed down from the mountains into the great valleys. On the side of the mountain north of the valley of Lightning Creek near Stanley, and 1,000 feet above the stream, a quartz ledge was seen to be scored by glacial markings trending northwestward parallel to the course of the valley.[1]

After existing for a long time, and in some cases extending far out over the plateau, even to the banks of the Fraser River itself, the local glaciers retired and disappeared, leaving behind them extensive sheets and deposits of boulder-clay, and large moraines; the latter dammed many valleys and diverted streams into other channels, thus adding to the intricacies of a drainage system which was already quite complicated in pre-Glacial times.

Most, if not all of the valleys had beds of pre-Glacial gravel of varying thickness covering their rocky floors. As the glaciers moved down the valleys they in many cases rode over this gravel and left it, with its cargo of gold, comparatively undisturbed, and at the same time they brought down a certain quantity of material from the hills on each side and formed ground moraines of hard massive impervious boulder-clay, which, on the retirement of the glaciers remained as watertight covers of varying thickness over the underlying gravel. Existing streams usually flow on the top of this bed of boulder-clay. In some narrower and swifter places in the upper reaches of valleys they have doubtless cut through it to the underlying gravel or bedrock, and many of the earlier mining operations were probably carried on in places where this had occurred. In these places all the gravel down to bedrock, as well as the upper part of bedrock

[1] "Was there a Cordilleran Glacier in British Columbia," by J. B. Tyrrell, *Jour. of Geol.*, Vol. 27, No. 1, 1919, pp. 55–60.

itself, was shovelled into the sluice-boxes, and washed to recover the gold.

In those parts of the bottoms of valleys where boulder-clay was still lying undisturbed on the gravel the miners sank shafts through the boulder-clay and gravels to bedrock, drove tunnels on or in bedrock, pumped the water from them with Cornish pumps, and extracted the gold-bearing gravel from the shafts. As the gravel was usually porous, the flow of water was often large and difficult to handle with the pumps. In fact, in long stretches of several of the valleys, where the pre-Glacial gravels have been buried to a great depth it has been found impossible to mine, or even to explore them on account of the heavy flow and heavy pressure of water encountered. Further attempts will doubtless be made to explore these deep gravels, but if such enterprises should be undertaken there should be made careful physiographic surveys of the district in order to determine the particular valleys or parts of valleys into which most gold was discharged, and the localities in which it probably lodged.

An interesting feature was observed on some of the gulches tributary to the larger valleys, as for instance on those of Mosquito and Last Chance Creeks. Both these streams flow in channels bounded by rock on their western or down-stream sides, and boulder-clay on their eastern or upstream sides. In searching for a paystreak in each case the old miners found that the pre-Glacial channel was buried beneath the boulder-clay on the eastern side of, and at considerably lower level than, the present stream, for the glaciers, as they descended the main valleys, had filled the upper sides of the gulches with boulder-clay, and, when drainage was re-established in post-Glacial times, the new channels were formed above and to the west of the old ones.

At the Cañon on Williams Creek, where two narrow gorges have been cut on opposite sides of a rocky knoll, the direction of movement of the glacier would appear to have been more or less transverse to the course of the stream at this point, and the glacier completely filled and covered up the eastern of the two gorges with boulder clay, so that it was not until some little time

after mining was begun on the creek that this gorge was found and uncovered.

The valleys so far referred to have had beds of pre-Glacial gravel remaining in them, but two valleys, or possibly parts of one valley, which came under my notice, namely, Stout-Lowhee and Chisholm Creek valleys, were different from the rest in this particular, for either most of the gravels which had originally covered their floors had been removed before the advent of the glacier, or possibly the glacier itself may have displaced what remained of the gravel, and may have kneaded it up with material brought from elsewhere to form the boulder-clay which is now either resting directly on bedrock, or is separated from it by a thin layer of poorly assorted material (Plate X., *c*.) This absence of gravel between the boulder clay and the underlying rock is well shown in a long tunnel into the western side of the valley of Chisholm Creek. Also the hydraulic operations which were being carried on in Stout Gulch at the time of my visit exposed an excellent section of boulder clay, which seemed to be fairly homogeneous from top to bottom. Some of it was slightly auriferous. On Mosquito Gulch, where hydraulic operations were also being conducted, and where boulder-clay along with both overlying and underlying gravel was being broken down and washed through sluice boxes, some of it was decidedly auriferous.

In addition to forming a blanket over the earlier gold-bearing gravels the boulder-clay would appear to have been deposited in some places of sufficient thickness to divert streams into new channels, as for instance at Beaver Pass House, Lightning Creek has been diverted to a narrow western from a wide northern channel, probably on account of the deposition of a thick bed of boulder-clay in the latter.

In addition to the deposition of a bed of boulder-clay over most of the surface of the lower land the glacier formed terminal moraines across the bottoms of the valleys. One of the most conspicuous of these is in Slough Creek valley, and extends from the west end of Jack-of-Clubs lake for several miles westward to a point some little distance below the mouth of Devils' Creek.

This moraine blocks the drainage of the valley, and forces the water issuing from Jack-of-Clubs lake to flow down the valley of Willow River.

Another hilly and stony moraine lies in the bottom of the valley of Lightning Creek between the mouths of Chisholm and Davis Creeks, but it had no influence on the general drainage except temporarily to dam back the water into a small lake.

Altogether the diversion of drainage from one valley to another would seem to have been affected much more by stream piracy in pre-Glacial times than by moraines or other dams in Glacial or post-Glacial times.

DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, Sheffield Scientific School of Yale University, New Haven, Conn. The full name of the author should be attached to all communications.

GRAPHIC DETERMINATION OF DIP COMPONENTS WHERE DIPS ARE MEASURED IN FEET PER MILE.

Sir: I was very much interested in Mr. Lahee's "Discussion" in a recent number of ECONOMIC GEOLOGY. Although I have not had occasion to work the problem for which his chart is designed, I have developed alignment diagrams for the solution of other trigonometric problems met with in structural and stratigraphic work.[1]

Charts composed of families of curves and straight lines have the disadvantage that the multiplicity of lines is confusing to the eye and prone to lead to mistakes. If, on the other hand, the lines are so few that the eye is not confused, they are so far apart that interpolation becomes difficult. With alignment diagrams all subdivisions necessary for keeping the error under one per cent. can be incorporated without making a cluttered appearance. With families of curves it is necessary to compute and plot a number of points for each curve in order that it may be accurately plotted throughout its length. I personally would prefer plotting the logarithmic scales of the inclosed chart to the labor

[1] Palmer, H. S., "Nomographic Solutions of Certain Stratigraphic Measurements," ECONOMIC GEOLOGY, vol. XI, No. 1, January, 1916.

Palmer, H. S., "New Graphic Method for Determining the Depth and Thickness of Strata and the Projection of Dip," U. S. Geol. Survey, Prof. Paper 120-*G*.

of algebraically computing the coördinates of a great number of points, but admit that this is entirely a matter of the personal equation. Mr. Lahee's chart has a distinct advantage over the

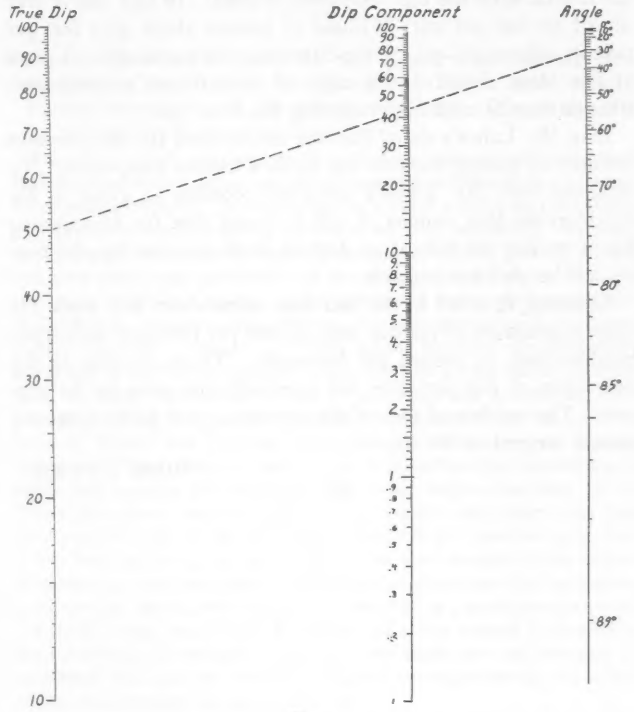


FIG. 23.

one submitted in that it can be used without having to provide a straight-edge or piece of thread.

Figure 23 is the alignment diagram prepared for finding the inclination in feet per mile in a direction not normal to the strike. Its use is illustrated for the same problem that Mr. Lahee gives by the broken line, which joins the point on the right scale repre-

senting the angle (between the directions of the true dip and the dip component) and the point on the left scale representing the dip in feet per mile. At the intersection of the dotted line with the middle scale the dip component is read. In this case a true dip of 50 feet per mile is found to become about 43.3 feet per mile in a direction 30° off the direction of the true dip. A piece of fine black thread or the edge of a draftsman's transparent triangle may be used for projecting the cross line.

Like Mr. Lahee's chart, this one can be used for the converse problem of getting the true dip from a known component. To illustrate with Mr. Lahee's corrected problem as given in his article in the May number, it will be found that for an apparent dip of 30 feet per mile at 40 degrees from the true dip, the true dip will be 38.8 feet per mile.

Attention is called to the fact that either chart will work for other expressions of the dip, such as feet per hundred, inches per hundred feet, or meters per kilometer. These, as well as the expression of feet per mile, are essentially the same as the tangent. The number of feet of dip per mile is just 5,280 times the natural tangent of the dip.

HAROLD S. PALMER.

REVIEW

Quicksilver Resources of California, with a section on metallurgy and ore-dressing. By WALTER W. BRADLEY. California State Mining Bureau, Bulletin No. 78, Sacramento, Cal., 1918. Price $1.50. 389 pp. with numerous maps and illustrations.

The short introductory chapter describes the uses of quicksilver and discusses production, prices and recent economic conditions in the quicksilver mining industry. It is followed by a brief chapter on the general geology of the deposits and on the theory of their deposition. Although this is a good summary, it cannot be said to contribute greatly to what had been previously published and leaves uncorrected much that was erroneous in earlier accounts of the geology of the quicksilver deposits of California. Chapter 3 describes the mercury minerals and associated gangue minerals. Chapter 4, of 176 pages, describes the quicksilver mines and prospects by counties and constitutes a very useful compendium of mines, equipment, owners or operators and production. The geologic maps in this section are mostly reproduced from the older reports of Becker and Forstner and retain the misleading and obsolete designation "metamorphic series" for a miscellaneous assemblage of rocks that includes the sandstone, shales and radiolarian chert of the Franciscan group, together with some serpentine and other rocks long since proved to be of igneous origin. There is no apparent recognition of the fact that the great ore bodies of the New Almaden mine instead of occurring in metamorphosed sedimentary rocks as described by Becker, were actually deposited in serpentine, which is an altered intrusive rock.

Part II., comprising a little less than half of the volume, is devoted to the metallurgy of quicksilver and contains much new and valuable information, including the results of original investigations by the author on the concentration of quicksilver ores.

The book is well written, excellently illustrated, rather unusually free from typographical errors, and well bound. Its handsome appearance and general character are highly creditable not only to the author but to the State Mining Bureau and to the printers. With due recognition of its deficiencies on the geological side, it can be heartily recommnded to all interested in quicksilver mining in California as a most valuable work of reference.

F. L. RANSOME.

SCIENTIFIC NOTES AND NEWS[1]

DAVIS B. REGER, assistant geologist of the West Virginia Geological Survey, will spend the next three months in Tucker County, W. Va., with local headquarters at Parsons.

E. H. SELLARDS has resigned as State Geologist of Florida to join the Bureau of Economic Geology of the University of Texas, Austin. He is succeeded by Herman Gunter, previously Assistant State Geologist.

DAVID T. DAY, of the Geological Survey, was recently in San Francisco.

FRANK W. DE WOLF, formerly with the U. S. Bureau of Mines, Washington, D. C., is now with the State Geological Survey, Urbana, Ill.

CHESTER NARAMORE has resigned from his position with the Bureau of Mines and is now with the Union Petroleum Co., Philadelphia, Pa.

MAX ROESLER announces his connection with the U. S. Geological Survey.

BURTON HARTLEY has returned to the Mid-Continent oil fields and formed the firm of Thomas & Hartley, consulting geologists, with offices at 509 National Bank of Commerce Building, San Antonio, Texas.

W. J. HAMILTON, consulting engineer of the Cerro de Pasxo Copper Co., J. M. Boutwell, consulting geologist, and C. V. Drew have sailed from New York for Lima.

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

H. S. GALE, of the U. S. Geological Survey, has returned to Paris from Alsace, where he has been studying the potash situation.

J. B. UMPLEBY, who was called to the Peace Conference as adviser on mineral resources, has returned to New York.

E. K. SOPER is now geologist with the Trinidad Petroleum Development Co., P. O. Box 175, Port of Spain, Trinidad, B. W. I.

JOHN A. UDDEN is chief geologist with the Sinclair Gulf Oil Co., Burk Burnett Bldg., Ft. Worth, Tex.

S. H. BALL has recently been in the Southwest.

C. H. CLAPP has been appointed director of the State Bureau of Mines at Butte. He will be geologist for the bureau.

L. S. NOBLE, of the Cresson Co., of Cripple Creek, is in Mexico.

L. R. SCHEURER has resigned from the Missouri School of Mines and has accepted a position with the North Georgia Agricultural College.

D. R. SEMMES, formerly professor of geology at the Texas A. & M. College, has opened an office for consulting work at 47 Petroleum Bldg., Fort Worth, Texas.

J. E. SPURR, executive of the War Minerals Investigation, will take charge of the physical examinations for the War Minerals Relief Commission.

W. W. MEIN has returned from Nicaragua.

F. G. STEVENS, Toronto, has returned from a three months' visit to Mexico, where he was examining properties.

W. R. INGALLS has retired from the editorship of the *Engineering and Mining Journal,* but will continue as consulting editor. He has resumed practice as consulting engineer with office in No. 115 Broadway, New York.

DAVID IRWIN has accepted a position with the Phelps-Dodge Corpn. at Douglas, Ariz.

VAN H. MANNING has been made a member of the Coal Export Committee of the American Mining Congress.

ALFRED ROOS, consulting and mining engineer, has been examining the Tulorosa Basin oil field for an association of Arizona mining men, headed by Edward Bush of Tucson, Ariz.

DONALD MACKENZIE is making a study of the Tularosa Basin in Otero County, N. M., for E. W. Hartman.

H. FOSTER BAIN, assistant director of the Bureau of Mines, has resigned from that position and will leave for China early this month.

P. K. LUCKE has changed his address to the following: Avenida Isabel La Catolica Num. 25, Mexico City.

L. D. DAVENPORT, mining engineer for the Oliver Iron Mining Co., has returned from California.

B. R. MACKAY will be in charge of a party sent out by the U. S. Geological Survey, to make explorations in British Columbia.

E. A. SPORLEY, of the Bureau of Mines, has been inspecting the Mesabi Range Mines.

HOWARD BANCROFT, of Denver, will be associated with B. L. Thane after June 1, with headquarters in the Croker Bldg., San Francisco.

IRA B. JEROLEMAN, geologist for the Calumet & Arizona Company at Warren, has again taken up his work.

ALBERT BURCH has been in El Dorado County, California, examining gold properties.

K. POMMERANTZ has resigned from his position with the So. American Metal Co. and has opened offices at Casilla 489, Santiago de Chine, Chile, S. A., as consulting engineer.

T. J. JONES has sailed for Vladivostock on his way to Kyshtim, Siberia.

A. A. HUBBELL, of the *Engineering and Mining Journal,* is visiting mining districts of the West.

W. H. BLACKBURN, superintendent for the Tonopah Mining Co., has returned from Nicaragua to Nevada.